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ROTATIONAL MOLDED PLASTIC TRICON CONTAINERS

W. P. Benjamin, et al

Boeing Company

Prepared for:

Army Mobility Equipment Research and Development Center

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UNITED STATES ARMY MOBILITY EQUIPMENT
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FORT BELVOIR, VIRGINIA

CONTRACT DAAK02-71-C-0201

Submitted by

THE BOEING COMPANY
MANUFACTURING RESEARCH AND DEVELOPMENT
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RENTON, WASHINGTON

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13. ABSTRACT

This document reports on a study to determine the feasibility of fabricating a full size TRICON container by encapsulating a metal structural framework with a plastic material by using the rotational molding process. The effort included a survey of commercially available rotational molding grade plastics and metals, the design and fabrication of a subscale mold and subscale containers. It was felt that a plastic encapsulated container would eliminate or minimize maintenance and repair costs of TRICON containers by reducing their susceptibility to rust, corrosion, dry rot, electrolysis, and impact damage.

Materials were selected, and a subscale mold was fabricated. Techniques were developed for encapsulating a structural framework with plastic using the rotational molding process. However, stress cracks developed in the plastic after molding. Although several technical approaches were attempted, techniques for eliminating the stress cracks could not be developed. The program is being redirected toward other approaches to plastic or plastic coated containers.

This interim report contains a body of information on molding characteristics of various rotational molding grade plastics not previously available to the plastics industry.

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1.0 SUMMARY

This program was stimulated by the interest of USAMERDC in the potential use of plastics as a containerized cargo container material. Specifically, the program was sponsored by USAMERDC to investigate the feasibility of fabricating 8 by 8 by 6-2/3 foot dry freight containers by utilizing the rotational molding process to encapsulate a metal framework with plastic. It was felt that the successful utilization of plastic in containers of this type would significantly reduce their total life cycle costs.

It was recognized at the outset of the program that the technology required to successfully fabricate containers by the concept under investigation was beyond the industry state-of-the-art. Both USAMERDC and Boeing acknowledged that it would be necessary to generate a significant amount of original and innovative materials and process data to develop the concept into a feasible process. With this in mind the program was organized to provide for the generation of original data and to establish feasibility on a subscale basis. The data generated during the subscale studies would then be used to establish design criteria and process parameters for the full size container.

The specific program tasks were as follows:

- Conduct a materials survey and select the most suitable plastic and metal materials.
- Design a subscale container and mold.
- Develop a manufacturing process, including a rotational molding cycle.
- Establish concept feasibility by molding subscale containers.
- Design a full-size Tricon container to meet the requirements of MIL-C-52661 (ME) and design a mold.
- Fabricate framework and mold six full-size containers for evaluation by USAMERDC.
- Document program activities in a comprehensive final report.

The initial activity in this program involved an in-depth study of the field of containerized shipment of cargo. Available literature and trade journals were helpful in providing insight into some of the problems related to containerized shipment. The entire shipment cycle was studied, including terminal facilities, equipment and relative costs. Designs of existing dry freight containers and handling equipment were analyzed. On-site tours of the Port of Seattle were made, and meetings with the authorities at this facility were very helpful in improving our total comprehension of this complex subject. A review of MIL-C-52661(ME), "Military Specification, Container, Cargo," was conducted. Design objectives were established and coordinated with USAMERDC.

After a survey of plastic and metal materials, crosslinked polyethylene and steel were selected for the subscale phase of the program. A subscale container and mold were designed, using steel as the container framework and mold material. Four steel frameworks were encapsulated with crosslinked polyethylene by the rotational molding process. The encapsulation of the third framework was witnessed by the Contracting Officer's Representative. Shortly thereafter, cracks were observed in the plastic portion of the encapsulated subscale containers. Closer investigation led to the conclusion that the cracks were caused by tensile stress and were related to the nominal shrinkage of the crosslinked polyethylene. Nominal shrinkage is the shrinkage that occurs during the polymerization of a plastic material, and is usually expressed in inches per inch. As a general rule, the nominal shrinkage increases when the cooling cycle is prolonged. In this case, it was thought that the cooling cycle, being longer than anticipated, caused the shrinkage of the plastic to be greater than anticipated. When the plastic encapsulating the rigid metal structure shrunk more than had been anticipated, tensile stress cracks developed in the plastic.

It was apparent that additional research was necessary before it would be practical to scale up to a full size TRICON container. The contract was modified by USAMERDC to add a redesign of the subscale container and mold, as well as a materials study. The number of deliverable full-size TRICON was reduced from six to three to offset the additional work and to avoid increasing the contract price.

The subscale container framework and the subscale mold were redesigned in aluminum to increase thermal conductivity and reduce weight. Two subscale aluminum frameworks were constructed and an aluminum rotational mold was fabricated. Attempts to encapsulate the aluminum framework with crosslinked polyethylene by rotational molding were unsuccessful. These results were reported to USAMERDC. It was decided to continue and complete the design of the full size container and mold, and continue to work the problems of incomplete encapsulation and cracks during the process optimization study.

A study of the design materials interrelationship, including steel versus aluminum for the structural members and an analysis of different design configurations for the reinforcing members and sidewall panels, was conducted. Consideration was given to numerous rotational molding grade plastic materials capable of being pigmented olive drab. As a result, aluminum was selected for the container framework and the mold. Crosslinked polyethylene was chosen as the encapsulating plastic. The design of the full size container and mold was finalized.

A prime objective of the Process Optimization Study was to establish the process limitations. This included studies of plastic flow characteristics during rotomolding, establishing optimum molding temperatures for various plastics, determining the optimum spacing between the metal framework and the mold wall, and identifying the optimum relationship between metal web width and opening width on the sidewall panels. The critical thermal rates for heating and cooling were also determined.

An attempt was made to encapsulate an additional aluminum subscale framework, using the optimum molding temperature identified in the process optimization study. The rotational molding equipment was modified to increase the cooling water capacity. Despite these measures, the encapsulation attempt was unsuccessful. Several areas of the framework were not covered by the plastic and stress cracks developed immediately after molding.

Although many avenues and approaches were explored, three problems persisted throughout the program. They were (1) the elimination of stress cracks, (2) achievement of thorough encapsulation, and (3) a strong plastic to metal bond. The data generated during the program present a paradoxical situation. For example:

1. Test data generated early in the program indicated that shrinkage of the plastic could be significantly reduced by shortening the cooling time. However, the mass of metal framework and plastic could not be cooled at a sufficient rate with existing equipment to reduce the shrinkage.

2. The encapsulation studies demonstrated that the maximum metal width that could be encapsulated was 1-1/2 inch. In order to meet the strength requirement of the TRICON container, it was determined that the corner posts must be at least 4 inches wide.

3. The addition of chopped fiberglass strands to the plastic material was shown to reduce the nominal shrinkage of the material. However, when fiberglass of sufficient quantity to reduce shrinkage was added, it was found that the plastic would not flow sufficiently to encapsulate the metal insert.

It should be noted that this program did produce a substantial body of original data related to the rotational molding process and rotational molding grade plastics. This data not only advances the state-of-the-art, but can be used to advantage by the plastics industry in general. Examples of the type of original information generated under this program are:

1. Comparative evaluations of parting agents for the rotational molding process.

2. Molding characteristics of rotational molding grade plastics.

3. Studies on preparation of metal surfaces to achieve a good adhesive bond with rotational molded plastics.

4. Encapsulation studies, including data on web-opening relationships, mold-insert spacing, and molding cycles covering a variety of thermoplastic material and plastic-fiberglass blends.

5. Techniques for rotational molding blends of plastics and chopped fiberglass strands.

6. Shrinkage versus percent of fiberglass curves for a variety of rotational molding grade plastics.

7. Shrinkage versus cooling rate curves for a variety of rotational molding grade plastics.

As a result of the work conducted under this program, the following conclusions have been made:

1. With existing state-of-the-art technology and rotational molding equipment, there is a low probability of successfully encapsulating a full size TRICON meeting the requirements of MIL-C-52661(ME). While it has been shown that it is possible to encapsulate small perforated metal panels, it has been amply demonstrated that the technology is not available for encapsulating a structural framework in combination with similar panels.

2. Of the release agents evaluated, the Ram GS-3 fluorocarbon produced the best surface finish on the molded part.

3. The CL-100 crosslinked polyethylene proved to be the most easily molded and best suited to the encapsulation of metal inserts.

4. The nominal shrinkage of a rotational molded plastic can be reduced by the addition of chopped fiberglass strands.

5. The nominal shrinkage of a rotational molded plastic can be reduced by increasing the cooling rate of the molding cycle.

6. The addition of chopped fiberglass strands to crosslinked polyethylene alters the flow characteristics of the plastic sufficiently to prevent encapsulation of a metal insert.

7. Aluminum, sandblasted and solvent cleaned, produced the best adhesive bond with all three plastics tested.

8. The program was successful in developing a body of original information on the rotational molding process and rotational molding grade plastics. This information advances the state-of-the-art and benefits the plastics industry as a whole.

The following recommendations are made as a result of work completed under this contract.

1. That no further attempt be made to develop the capability of rotational molding a plastic TRICON container by encapsulating a metal framework.

2. That alternative approaches to the development of plastic TRICON containers be considered.

3. That the body of information generated during this program be published, thereby advancing the plastics industry state-of-the-art.

This document has been prepared at the request of USAMERDC to report in detail all work accomplished under this program to date.

2.0 INTRODUCTION

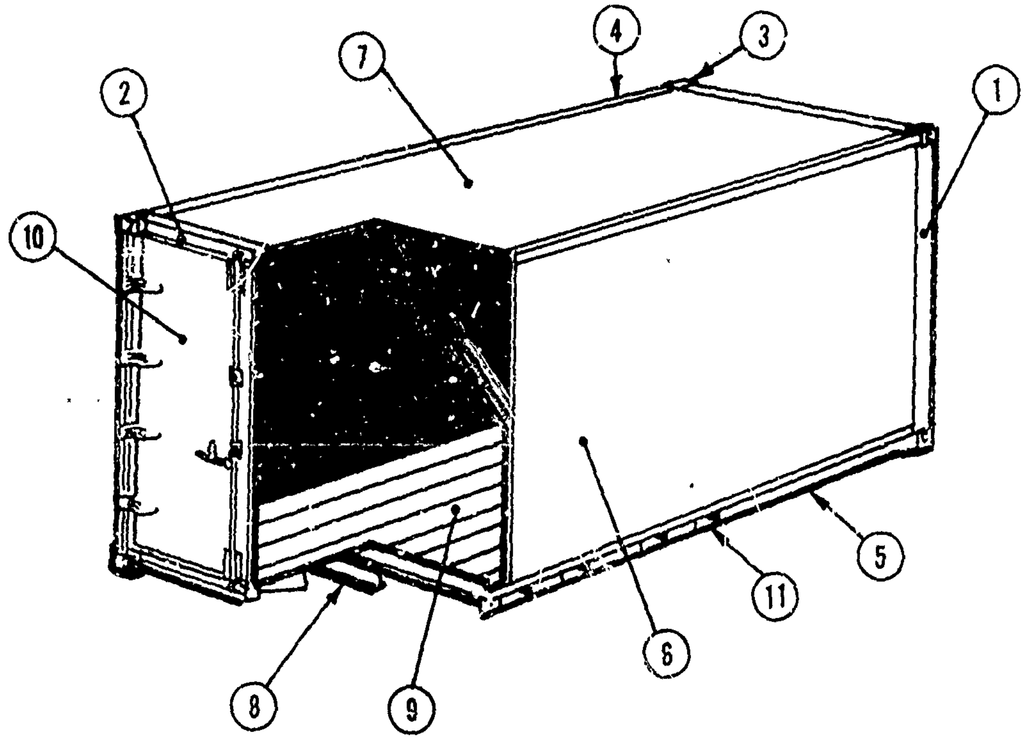
2.1 BACKGROUND

Containerization is the term applied to the large scale unitization of cargoes by means of reusable, standardized boxes. The beginning of the era of containerization was in October 1957, when the first fully containerized ship was put into regular service. Since that time, containerization has had a significant impact on the economics of cargo transport. Figure 1 shows a typical 8 by 8 by 20 foot dry freight container, sometimes referred to as an intermodal container.

The main advantage of containerization is that a high degree of mechanization in loading and unloading of ships is possible, which greatly increases efficiency and speed of cargo transfers. This point assumes even greater significance when it is noted that loading and unloading represents 40-50% of the total cost of shipping a cargo from its point of origin to its final destination. Because containerization results in lower cost per container handled, it has had phenomenal growth.

The various branches of the U. S. Armed Forces have been quick to recognize the potential benefits of containerization to military operations. The use of containerized shipment in military operations rapidly translates into (1) shorter flow time of critical supplies from point of origin into combat areas, (2) speedy cargo handling, consequently faster turn-around of ships, (3) less ships required to transport the same volume of cargo, (4) decrease of supplies required to be stored overseas (strategic reserves) and (5) greater economy in transporting military cargo.

A study sponsored by the U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, was a milestone in placing the present state-of-the-art of containerization in its proper perspective. The final report, entitled "A Critical Analysis of the State of the Art in Containerization" indicates that maintenance and refurbishment costs on containers meet or exceed



LEGEND:

1 REAR END FRAMES
2 FRONT END FRAMES
3 CORNER FITTINGS
4 SIDE RAILS
5 SIDE RAILS
6 SIDE PANELS
7 ROOF
8 CROSS MEMBERS
9 DECK SURFACE
10 DOORS
11 FORKLIFT POCKETS

FIGURE 1

TYPICAL INTERMODAL CONTAINER

the original purchase price of the containers. This has led to an interest on the part of the U. S. Armed Forces in developing containers with lower life cycle costs.

Further study of presently utilized containers indicates that most are made of wood, steel or aluminum. Containers fabricated with these materials have certain obvious disadvantages, such as susceptibility to rust, corrosion, electrolysis, dry rot, insect attack, and impact damage.

The use of plastics as container materials offers an outstanding potential to reduce life cycle costs. They are capable of performing the functions of containment and protection under extreme environmental conditions such as temperature extremes, severe impact, vibration and compression loads, exposure to acids and chemicals, and UV and IR radiation. These characteristics indicate that plastic containers offer an increased life span and lower maintenance costs than containers made of conventional materials.

Containerization, when applied to military logistics operations, presents some unique problems uncommon to commercial cargo transport operations. While there is no firm policy with regard to military container requirements the following general requirements stand out as being important.

A. <u>Rapid loading and unloading.</u> The ability to quickly load and/or unload ships during military operations is desirable.

B. <u>Maximum access to container contents.</u> Upon its receipt by the user, the container may be used as a field storage bin. Consequently, the more readily accessible the contents, the more suitable a container is for military applications.

C. <u>Intermodal.</u> A military container must be truly an intermodal container. In a contingency, containers would be transported within the heavy airlift logistics system as well as by sea and land transport means. Aircraft such as the C-130, C-141 and C-5 would be utilized. Containers must be compatible with the 463L aircraft handling system currently in use. In considering air

shipment, the tare weight of the container becomes an important consideration. In forward areas, where large handling facilities are not available, containers must be capable of being transported by helicopter and available ground vehicles.

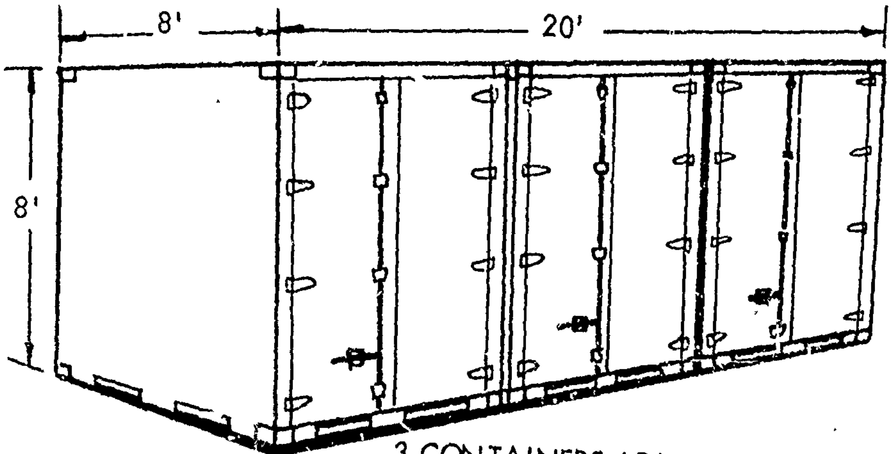
D. Break-bulk requirements. The military logistics systems have provisions for receiving area/break bulk points where goods are separated and routed to field users. These points are normally located near major terminals. Suppliers going to the field may be transported by truck or, in difficult terrain, by helicopter.

To meet these special military requirements, the U. S. Army has developed the TRICON concept, whereby the standard 8 x 8 x 20 foot container is divided into 3 units 8 x 8 x 6-2/3 feet in size (see Figure 2). The unit has full access double doors with standard commercial locks and hinges. These containers can be coupled together in groups of three to form a standard 20-foot container. The frame of the container has sufficient strength to withstand the loads imposed when TRICON's are coupled in groups of three and handled as a 20 foot unit. Corner fittings at each of the eight corners of the container provide easily accessible external handling and tie-down locations.

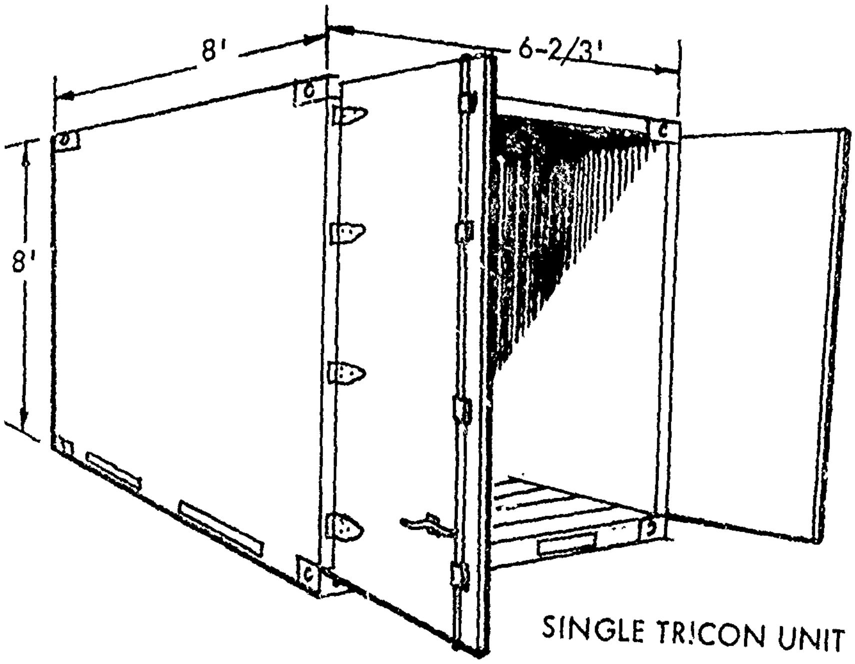
As a manufacture of commercial and military aircraft, Boeing has been closely associated with the development of intermodal containers and has worked closely with road, rail, sea and air operators on a number of national and international carrier committees. Recognizing the potential advantages of plastic intermodal containers, The Boeing Company assigned its engineers the task of developing a plastic intermodal container concept applicable to the U. S. Army TRICON program, as well as the commercial containerized shipment industry.

THE BOEING TRICON CONCEPT

The TRICON container concept developed by Boeing involves the use of the rotational molding process. The rotational molding process is simple in principle. A predetermined amount of plastic material, in the form of a finely ground powder or liquid, is placed inside a mold which is then completely sealed. The amount of plastic material in the mold determines the wall thickness of the part. The mold is placed in an oven and heated to a temperature sufficient to cause the plastic



3 CONTAINERS JOINED TOGETHER FORM 20 FOOT LONG SHIPPING UNITS WHICH MEETS COMMERCIAL RAIL, ROAD, AND WATER CARRIER STANDARDS



SINGLE TRICON UNIT

FIGURE 2

TRICON CONTAINER CONCEPT

to fuse to the sides of the mold. The mold is rotated simultaneously on two axes while it is in the oven. The plastic material tumbles inside the mold and forms a uniform coating on the inside of the mold. The mold is then cooled, opened, and the part is removed. (See Figure 3.)

The Boeing Tricon concept consisted of utilizing the rotational molding process to completely encapsulate a metal structural framework. This involved fabricating a simple metal framework, adding expanded metal or wire mesh, positioning it inside the mold along with a charge of plastic, and rotational molding the container. (See Figure 4.) By this means the framework becomes an integral part of the container. It was planned that provisions could be made for integrally molding inserts which would later serve as attachment points for handles, couplings, hinges, and other required hardware.

It was felt that a container of this type would offer the following advantages over existing containers:

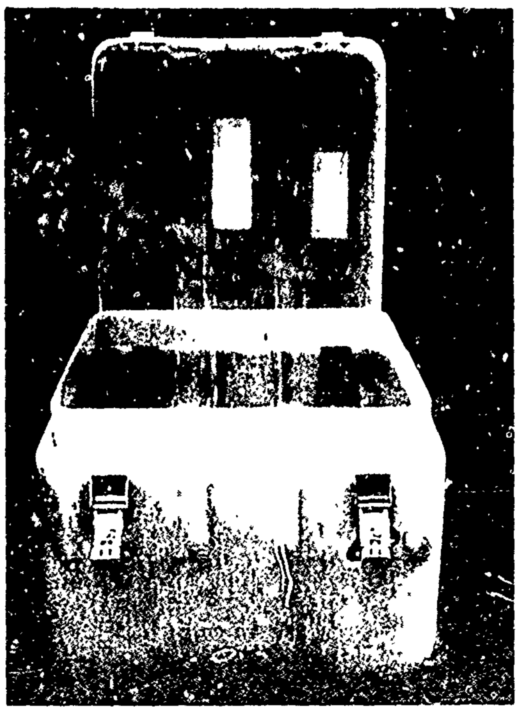
1. Low maintenance requirements.
2. Seamless, therefore watertight.
3. Strength and durability.
4. Resistance to corrosion and/or other effects of chemicals and weathering.
5. Elimination of the need for decorative or protective painting through pigmentation of the plastic.

This concept was presented to the Materials Handling Equipment Branch, U. S. Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia, in Technical Proposal D6-22235, entitled "Plastic Sealand-Air Containers, Tricon Concept." In this document it was proposed that a research and development program be conducted for the purpose of determining the feasibility of this concept and fabricating both test and prototype hardware.

Polycarbonate Powder Is Measured and Poured Into the Container Mold

The Mold Is Mounted on the Rotational Molding Machine and the Part Is Formed

Polycarbonate Container Is Removed From the Mold



Completed Container After Trimming and Attachment of Accessories

FIGURE 3

ROTATIONAL MOLDING PROCESS SEQUENCE

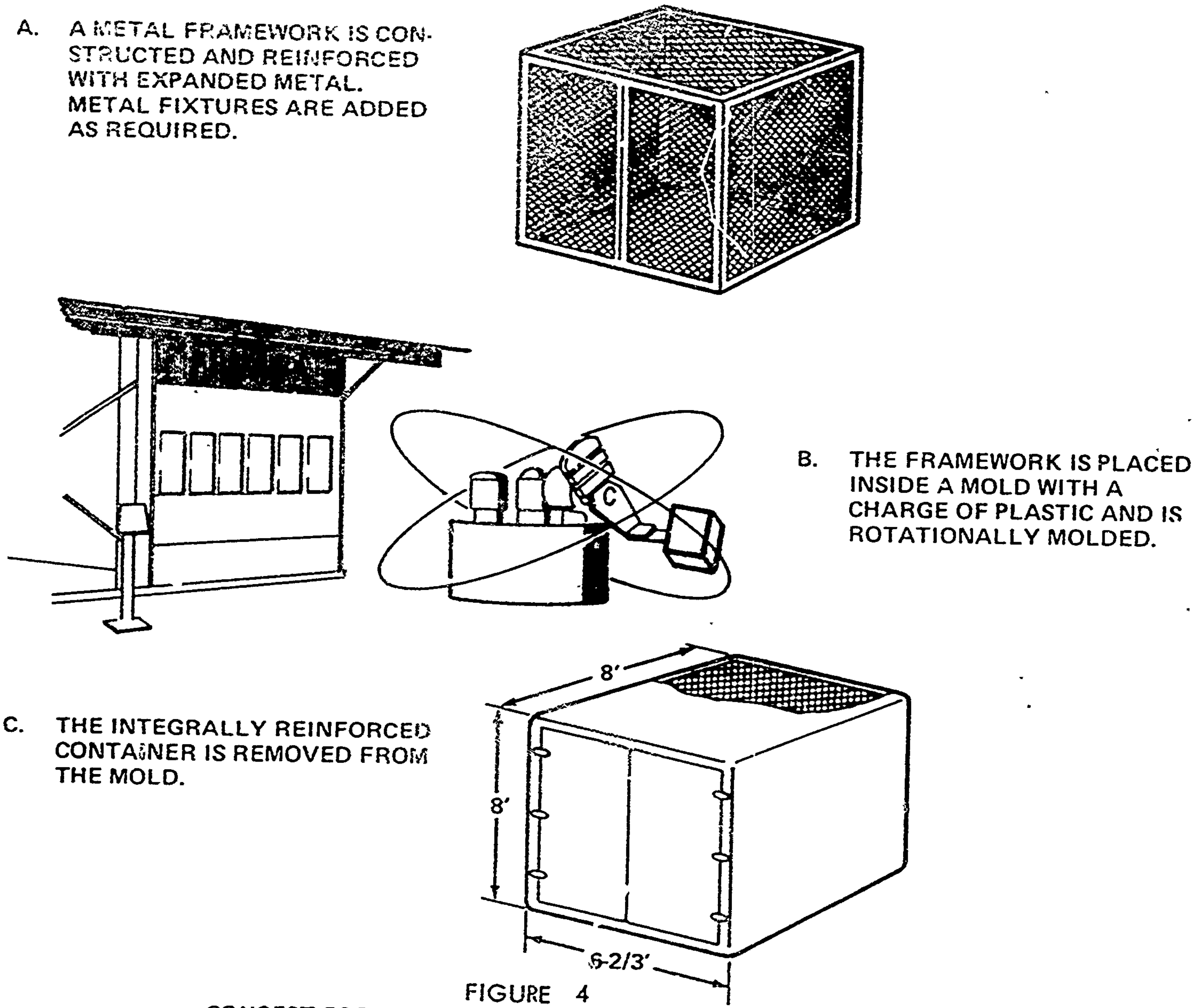


FIGURE 4
–CONCEPT FOR INTEGRALLY-REINFORCED PLASTIC CARGO CONTAINER

2.2 PROGRAM OBJECTIVE

Contract DAAK02-71-C-0201, "Rotational Molded Plastic TRICON Containers" was awarded to The Boeing Company. The main objective was to establish the feasibility of making dry freight containers by the proposed method. This objective was to be accomplished by making both subscale and full-size containers.

Specific tasks required to meet the program objective were as follows:

1. Establish container strength requirements.
2. Select optimum rotational molding grade plastic.
3. Select metal framework material.
4. Design a subscale(4' x 4' x 3') TRICON container.
5. Design and fabricate mold for subscale container.
6. Demonstrate process feasibility by rotational molding subscale containers.
7. Conduct an engineering review of the subscale container.
8. Design full size TRICON container.
9. Design and fabricate full size mold.
10. Mold six (6) full size TRICON containers.
11. Submit full size containers to USAMERDC for evaluation.
12. Prepare final technical report and other appropriate documentation.

The program was to be conducted in four phases over a period of twenty-four (24) months.

3.0 INVESTIGATION

3.1 PRELIMINARY INVESTIGATION

3.1.1 Problem Understanding

The first task undertaken in this program was the development of a body of information related to containerization that would provide a basis for the materials selection and design effort to take place later in the program. It was the expressed desire of the Contracting Officer's Representative that we have a thorough understanding of containerization in general, as well as an insight into some of the less obvious, but important, problems faced by the container industry.

Initially, a review of trade journals and available documents on containerization was conducted by the engineers assigned to the program. Attachment B to the contract, entitled "A Critical Analysis of the State of the Art in Containerization" proved to be the most comprehensive and complete body of information available on the subject of containerization. This document was referred to frequently during the course of the program.

The personnel assigned to the contract also made visits to the Port of Seattle for first-hand observation of container cargo handling methods and equipment used in loading and unloading of cargo ships. Discussions with Port of Seattle management were very helpful in identifying problem areas. Damage to various containers was observed, and photographs were taken to record the extent of damage, cause of damage, and container material and construction.

The contract and Attachment I to the contract "MIL-C-52661 (ME), Military Specification, Container, Cargo," were thoroughly reviewed. Although the specification covered a 20 foot container and did not specifically apply to the TRICON container, design load requirements were calculated (see Figure 5). These requirements were reviewed and approved by the Contracting Officer's Representative. They thereby became design objectives for the rotational molded TRICON container.

TYPE LOAD	UNIT AND LOAD
Stacking S	Load test 77-1/2 inch unit to 26,879 pounds gross weight. Apply 100,800 pounds vertical load (S) to each top corner fitting in turn. Load S = 100,800 pounds
Lifting From Top T	Couple three 77-1/2 inch units together. Load to total gross weight of 89,600 pounds. Lift by the 4 top corner fittings using hooks in end holes or side holes. Load T = 22,400 pounds
Lifting From Bottom L	Couple three 77-1/2 inch units together. Load to total gross weight of 89,600 pounds. Attach sling to side holes in bottom corner fitting with line of action at 30° to the horizontal, and lift. Load L = 22,400/sine 30° = 44,800 pounds. Vertical component = 22,400 pounds, horizontal component = 39,000 pounds.
Horizontal Restraint B	Couple three 77-1/2 inch units together. Load to total gross weight of 4[illegible]0 pounds. Apply a compression load B, and then a tension load to each lower side rail in turn. Load B = (1.25) (gross weight) = 56,000 pounds.
Floor Load	(1) Load floor to a uniformly distributed load of 30,000 pounds (2) Load floor to a concentrated load of 6000 pounds over an area 3 x 7-1/3 inches.
Roof Load	Load roof to 660 pounds uniformly distributed over 12 x 24 inch area.
Wall Side Load W	(1) Apply a uniformly distributed load of 5460 pounds to either the R.H. or L.H. end wall. (2) Apply a uniformly distributed load of 8100 pounds to the door side and the blind side in turn.
Racking R	Restrain container through bottom corner fittings. Apply a compression and a tension load laterally and longitudinally, in turn, of 35,000 pounds to each top corner fitting in turn.

FIGURE 5

TRICON CONTAINER DESIGN LOAD REQUIREMENTS

3.1.2 Plastic Materials Evaluation

The first step in the evaluation of plastic materials for the TRICON container was to determine which materials were produced in rotational molding grades. This exercise narrowed the field to 8 candidate materials; linear polyethylene, cross-linked polyethylene, Nylon 11, Ionomer, polycarbonate, polysulfone, acetal, and polyvinyl chloride. Technical data sheets were obtained from materials suppliers and the comparative property charts shown in Figures 6 and 7 were made.

The next step was to establish criteria for the selection of the optimum plastic material. The following criteria were selected as being most important for the successful molding and subsequent in-service performance of a plastic TRICON container.

1. Good flow characteristics - The degree of success achieved in encapsulation of the reinforcing structure is directly related to the flow characteristics of the plastic. The better the flow characteristics of the plastic, the better the chances of successfully encapsulating the reinforcing structure.

2. Resistance to the effects of chemicals, radiation and fire - One of the primary reasons for the interest in plastic containers is the potential for reduced maintenance and refurbishment costs because of improved resistance to deterioration from the effects of chemicals, solvents, weathering (including UV and IR radiation) insects, and corrosion. The material selected must provide these qualities.

3. Good Impact Strength - The plastic TRICON container will be required to perform the functions of containment and protection under extreme environmental conditions. Containers of this type are subjected to severe impact loads. The plastic material selected must be able to withstand impact loads when at service temperatures ranging from -40°F to +140°F.

4. Cost - It was decided that, in the event that all other characteristics were equal, the cost of the plastic material would be the basis for final selection.

MATERIAL	IMPACT STRENGTH FT LB/IN NOTCH	TENSILE STRENGTH PSI	HEAT DEFORMATION @ 264 PSI	SPECIFIC GRAVITY
High Density Polyethylene	10	3,000	120°F	0.95
Crosslinked Polyethylene	16	2,500	160°F	1.10
Nylon II	1.8	8,000	130°F	1.05
Ionomer	20	1,500	90°F	.94
Polycarbonate	16	9,000	265°F	1.21
Polysulfone	16	10,200	345°F	1.24
Acetal	2.0	9,000	230°F	1.41
PVC	12	8,500	234°F	1.49

FIGURE 6

TYPICAL PHYSICAL PROPERTIES OF ROTATIONAL MOLDING GRADE PLASTICS

MATERIAL	RESISTANCE TO ACIDS	RESISTANCE TO ALKALIES	RESISTANCE TO ULTRA-VIOLET	RESISTANCE TO INFRA-RED	RESISTANCE TO FIRE
Polyethylene	Excellent	Excellent	Poor - requires additives	Good below 160°F	Slow burning
Crosslinked Polyethylene	Excellent	Excellent	Good - with additives	Good below 200°F	Self-extinguishing
Ionomer	Excellent	Excellent	Poor	Good below 140°F	Slow burning
Nylon 11	Attacked	Excellent	Good	Good below 180°F	Self-extinguishing
Polycarbonate	Attacked	Attacked	Surface effect only	Good below 250°F	Self-extinguishing
Polysulfone	Excellent	Excellent	Fair	Good below 325°F	Self-extinguishing
Acetal	Attacked	Excellent	Good	Good	Slow burning
PVC	Excellent	Excellent	Excellent	Good below 160°F	Self-extinguishing

FIGURE 7

RESISTANCE OF VARIOUS THERMOPLASTICS TO THE EFFECTS OF CHEMICALS, RADIATION, AND FIRE

3.1.2.1 Comparison of Flow Characteristics

The flow characteristics of the eight candidate materials were then compared. To accomplish this, a point rating system was used. Point values were assigned as follows: EXCELLENT = 5, VERY GOOD = 4, GOOD = 3, FAIR = 2, and POOR = 1. It was decided that any material with a flow characteristic rating of less than 3 would be eliminated from further consideration.

Samples of the candidate materials were obtained, and small parts were molded. When extremely poor quality parts were obtained with PVC, it was learned from the manufacturer that the rotational molding grade PVC was still in an experimental status and had not been approved for production. PVC was eliminated from future consideration at this point. Parts were molded on the Mc-Neil Akron Model #500 rotocast equipment located in the Manufacturing Research and Development laboratory (Figure 8) with the other candidate plastic materials and ratings were assigned to each. The results are shown in Figure 9. Polycarbonate and polysulfone were eliminated at this point.

3.1.2.2 Comparison of the Resistance of Candidate Materials to the Effects of Chemicals, Radiation, and Fire

Using the data shown in Figure 6, the 5 remaining candidate materials were again rated for their degree of resistance to the effects of Chemicals, Radiation, and Fire. Points were assigned as follows:

- o Resistance to Acids Excellent = 1, Attacked 0
- o Resistance to Alkalies Excellent = 1, Attacked 0
- o Resistance to UV Good or Better = 1, Other = 0
- o Resistance to IR Good or Better = 1, Other = 0
- o Resistance to Fire Self-Extinguishing 1 = Slow Burning = 0

The results of this comparison are shown in Figure 10. Crosslinked polyethylene was the only candidate material to achieve a point rating of 5 by satisfying all the established physical and chemical criteria. Nylon 11 met all the requirements except resistance to acids, and was assigned a point rating of 4.

FIGURE 8

McNEIL-AKRON MODEL #500 ROTOCAST EQUIPMENT
LOCATED IN MANUFACTURING RESEARCH AND
DEVELOPMENT AUBURN LABORATORY

MATERIAL	FLOW CHARACTERISTIC RATING
High Density Polyethylene	3
Crosslinked Polyethylene	5
Nylon 11	5
Ionomer	4
Polycarbonate	1
Polysulfone	1
Acetal	5
PVC	1

EXCELLENT = 5
VERY GOOD = 4
GOOD = 3
FAIR = 2
POOR = 1

FIGURE 9

COMPARISON OF FLOW CHARACTERISTICS OF ROTATIONAL MOLDING GRADE PLASTICS

MATERIAL	RESISTANCE TO ACIDS	RESISTANCE TO ALKALIES	RESISTANCE TO ULTRA-VIOLET	RESISTANCE TO INFRA-RED	RESISTANCE TO FIRE	TOTAL POINTS
Polyethylene	1	1	0	1	0	3
Crosslinked Polyethylene	1	1	1	1	1	5
Ionomer	1	1	0	1	0	3
Nylon II	0	1	1	1	1	4
Acetal	0	1	1	1	0	3

FIGURE 10

RATING OF CANDIDATE MATERIALS - RESISTANCE TO THE EFFECTS OF CHEMICALS, RADIATION, AND FIRE

3.1.2.3 Comparison of Impact Strength of Candidate Materials

In using impact strength as a criteria for ranking the candidate materials, the results were as follows:

RANKING	MATERIAL	IMPACT STRENGTH FT LB/INCH NOTCH
1	Ionomer	20.0
2	Crosslinked Polyethylene	16.0
3	High Density Polyethylene	10.0
4	Acetal	2.0
5	Nylon 11	1.8

3.1.2.4 Cost Comparison

The cost per pound of production quantities of each of the candidate materials was obtained. These costs were as follows:

	MATERIAL	COST/LB
1.	High Density Polyethylene	$ .20
2.	Crosslinked Polyethylene	$ .38
3.	Ionomer	$ .90
4.	Acetal	$1.25
5.	Nylon 11	$3.00

3.1.2.5 Final Plastic Material Selection

As a result of the preceding studies, crosslinked polyethylene was selected as the plastic material for the subscale studies. This selection was based on the following rationale:

1. Crosslinked polyethylene was the only candidate material that satisfied the flow characteristics requirement and met <u>all</u> of the established criteria for resistance to the effects of chemicals, radiation, and fire.

2. Crosslinked polyethylene exhibited outstanding capability to withstand severe impact.

3. The cost per pound of crosslinked polyethylene was substantially lower than the other candidate materials, with the exception of high density polyethylene.

It was learned through conversations with the manufacturers laboratory personnel that the Ultra Violet resistance of high density polyethylene could be increased from poor to good with the addition of pigments. This information made high density polyethylene the second choice of the candidate materials on the strength of 1) acceptable flow characteristics, 2) meeting all chemical and radiation criteria, 3) its acceptable impact strength, and 4) the fact that it was the lowest cost per pound of all of the candidate plastic materials. It was decided that, should problems occur in the studies with crosslinked polyethylene, high density polyethylene would be used as an alternative material.

Parts were molded using various release agents to determine which release agents produced the best surface finish on the molded part. The results of these tests are shown in Figure 11. Based on these results, the decision was made to use Ram GS-3 for all future rotomolding with the olive drab crosslinked polyethylene.

3.1.3 Selection of Structural Material

First, a survey was made of materials most commonly used in the fabrication of intermodal containers. Figure 12 shows a tabulated comparison of the relevant material properties of the three final candidate materials that were considered for the subscale framework. At the 400-500°F contemplated molding temperature range, the strength of Al 6061-T6 drops off to only 50% of its initial value. With the exception of the Al 2219 alloy, all commonly used aluminum construction alloys show the same drastic strength reduction after prolonged exposure to the rotomolding temperatures involved, which approximate the annealing temperatures of those alloys. Since weight considerations and thermal conductivity characteristics were not of prime concern during the initial phase of the development program, common type A-36 (ASTM) construction steel was selected over Type 2219 aluminum as the structural material for the first subscale container. Additional prevailing factors which led to the selection of steel were substantial differences in material purchase costs as well as the ready availability of steel stock material and steel corner fittings.

RELEASE AGENT	TYPE	EFFECT ON MOLDED PART
Miller-Stevens 136	Fluorocarbon	Numerous pinholes on part surface
Dow-Corning R-671	Silicone Resin	Excessive warpage and poor release from mold
Ram GS-3	Fluorocarbon	Good, uniform surface
Frecote 33	Polymeric	Excessive dimpling of part surface

FIGURE 11

EFFECT OF VARIOUS RELEASE AGENTS ON ROTATIONAL MOLDED CROSSLINKED POLYETHYLENE

		AL 6061-T6	AL 2219-T87	STEEL, A 36 (ASTM)
DENSITY LB/IN^3		.098	.102	.28
THERMAL CONDUCTIVITY BTU/FT^2/IN/HR/°F		1070	1070	241
THERMAL EXPANSION IN/IN/°F		.0000131	.0000124	.00000633
ULTIMATE TENSILE STRENGTH - PSI	75°F	45,000	68,000	60,000
	500°F *	34,000	62,000	70,000
YIELD STRENGTH PSI	75°F	40,000	56,000	36,000
	500°F *	20,000	39,000	36,000
ELONGATION IN 2 IN., MIN., %	75°F	17%	12%	30%
	500°F	18%	21%	
MODULUS OF ELASTICITY PSI x 10^6	75°F	9.9	10.5	29
	500°F	7.9	8.5	

* AT ROOM TEMPERATURE AFTER 10 HOURS AT ELEVATED TEMPERATURE

FIGURE 12

PHYSICAL AND MECHANICAL PROPERTIES OF METALS CONSIDERED FOR CONTAINER STRUCTURE

3.2 SUBSCALE CONTAINER DESIGN AND MOLD DESIGN

3.2.1 Subscale Container Design

A. Design Objectives

Design and fabrication of a subscale container was considered to be of essential value during the preliminary investigation phase of the program. Its purpose was to obtain engineering data to support subsequent full size TRICON design, with the following objectives in mind:

1. Design and test a structural framework which meets the design load requirements of the full size TRICON container (see Figure 4).

2. Design a structural framework which is cost effective to manufacture. It was acknowledged that potentially large numbers of containers would be required to be fabricated following demonstration of concept feasibility.

3. Select a structural material that remains stable and shows no critical loss of physical and mechanical properties when exposed to molding process, temperatures. It was contemplated that the container structure would be exposed to temperatures in the range of 400-500°F.

4. Design a framework that is compatible with and can be used to index to a container mold. Index locations should hold the framework in a fixed position with relation to the mold throughout the rotational encapsulation cycle.

5. Provide test hardware suitable to establish feasibility of plastic encapsulation of the structural framework by rotational molding and further development of an optimum molding cycle.

6. Restrict weight and geometry of subscale container to facilitate rotomolding on the Boeing production McNeil-Akron Model 1700 machine, shown in Figure 13.

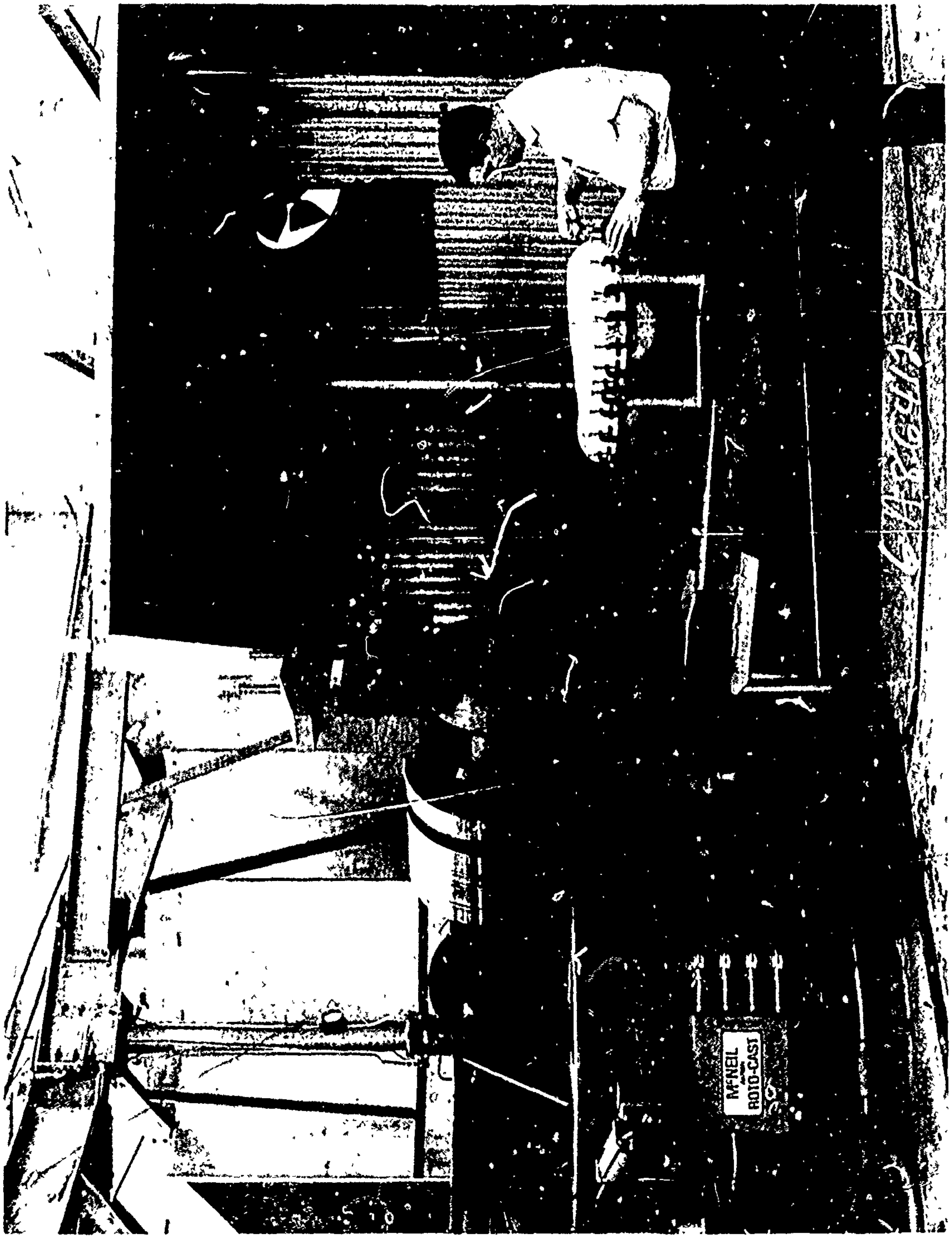


FIGURE 13

MCNEIL-AKRON MODEL 1700 ROTATIONAL MOLDING EQUIPMENT LOCATED AT AUBURN, WASHINGTON, FACILITY

B. Container Configuration

Following the material selection, a series of trade studies was conducted to determine the optimum configurations for the basic structural elements of the framework. For the purpose of the trade study the structure was subdivided into the following basic components:

1. Corner posts and rails.
2. Door sills and headers.
3. Sidewall panels.

For each component, various different configurations were evaluated on the basis of material cost, cost to fabricate to desired shape (including cutting, forming and welding) and total cost per linear foot or square foot for panel designs. For purposes of quick relative cost comparison, one configuration of each component group was arbitrarily selected as the reference baseline shape. Next, the material cost, labor cost, and total cost of the baseline configuration were assigned a cost merit index of 1.0. All other configurations were now rated with respect to the baseline shape; index numbers lower than one (1) represent the ratio of cost improvement over the baseline configuration, and vice versa. The tabulated results of the various trade studies based on equivalent strength and/or weight values, and a quantity production basis of 1000-5000 units are shown in Appendix A.

As a result of the trade study, the most cost effective configurations were selected for the steel subscale. Detail design of the subscale container is found in Appendix B, Tool Drawing R677059P02, Sheets 1 through 3.

Because of the still experimental nature of the subscale container, doors and hinge fittings were eliminated from the design. Also, as shown in Figure 14, only part of the container frame was designed with full scale frame members to reduce total weight of the structure and to prevent overloading of the Model 1700 rotomolding machine.

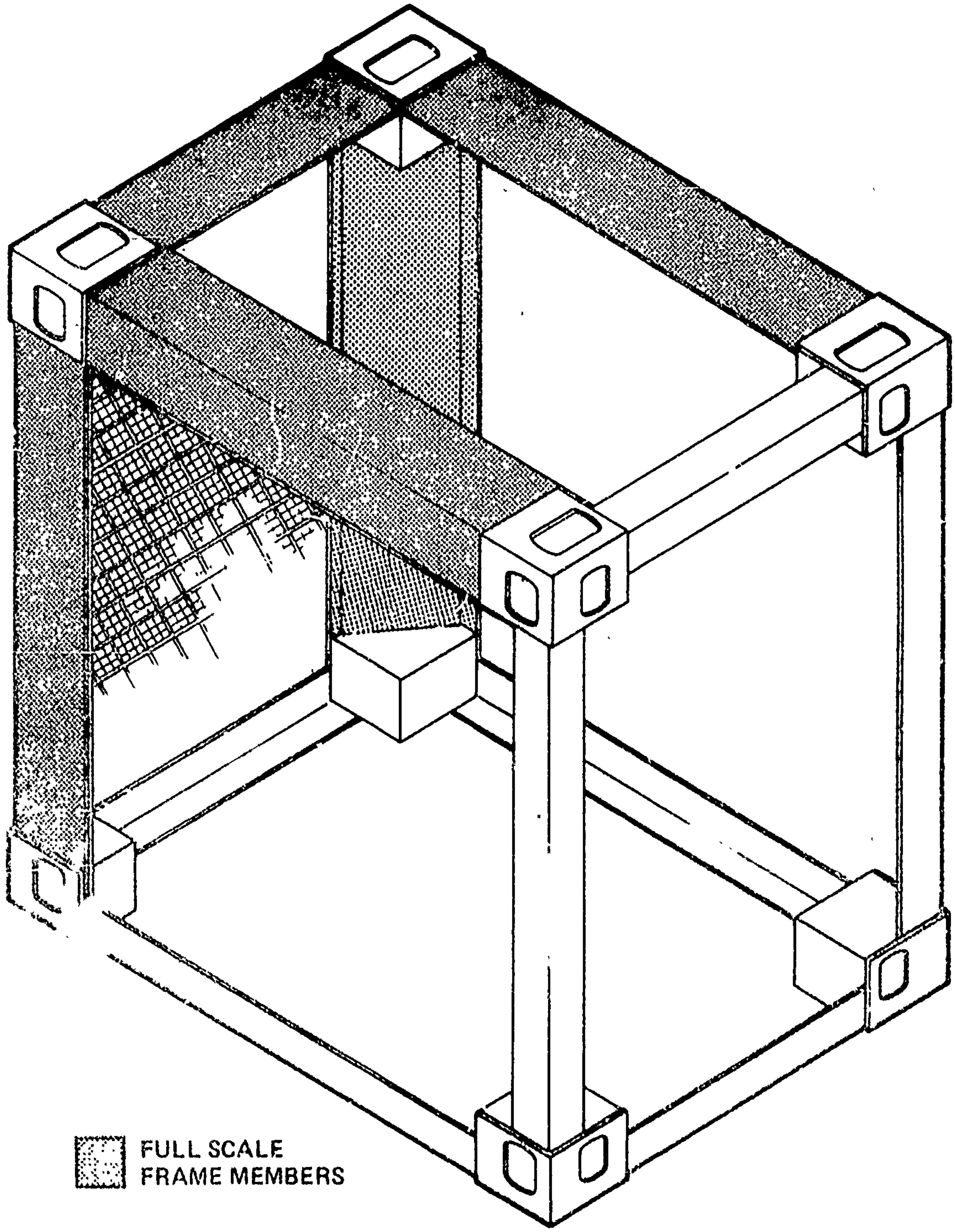


FIGURE 14

SUBSCALE CONTAINER FRAME

3.2.2 Subscale Mold Design and Fabrication

The subscale container mold was designed in steel plate to insure that the coefficients of linear thermal expansion of the mold and the subscale container framework were identical. Although the use of an aluminum mold would have decreased the weight of the mold and improved the thermal conductivity, it was recognized that the difference in thermal expansion would cause differential movement during the oven cycle. This could result in a considerable deviation from desired uniformity in the spacing between the inner mold wall and the subscale framework.

The mold was designed using 1/4 inch thick steel plate and steel angle. The base of the mold contained brackets for attaching the mold to the McNeil-Akron Model 1700 Rotocast equipment. Figure 15 shows the mold design concept. Figure 16 is a section through the mold.

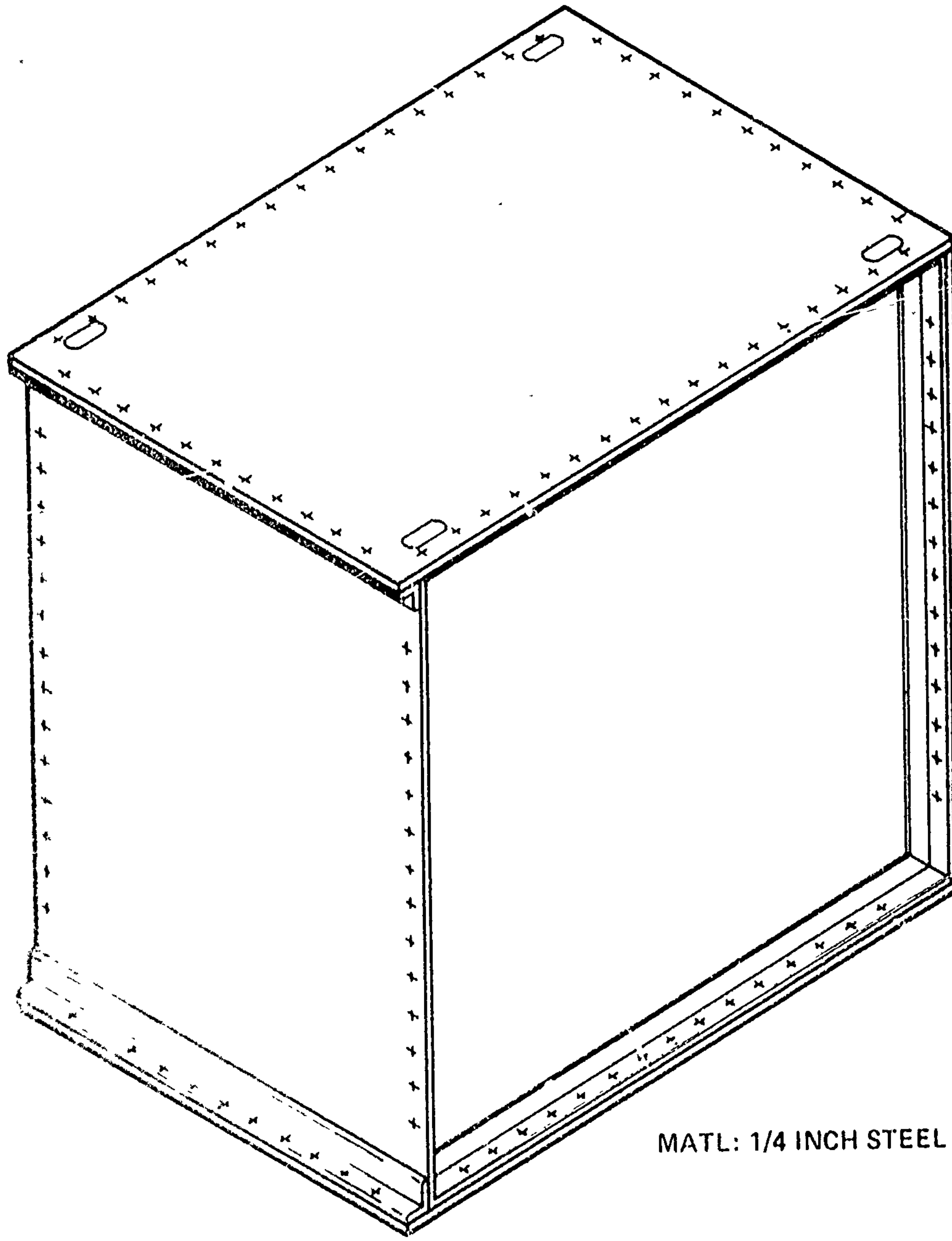
3.2.3 Manufacturing Process Development

A. Process and Assembly Sequence

For ease of fabrication, it was decided that frame and panel components were to be subassembled before final assembly of the sidewall panels into the container frame. The same fabrication sequence established for the full size TRICON assembly was also used for the subscale container fabrication for trial and evaluation purposes. The proposed production techniques proved to be practical during fabrication of the subscale container and no particular material handling problems nor processing difficulties were experienced.

The proposed fabrication sequence for the full size TRICON, shown chronologically in Figures 17 through 22, is as follows:

Figure 17 - Assemble right and left hand end frames
Figure 18 - Assemble wall and roof panels
Figure 19 - Assemble container frame



'FIGURE 15

STEEL SUBSCALE MOLD DESIGN

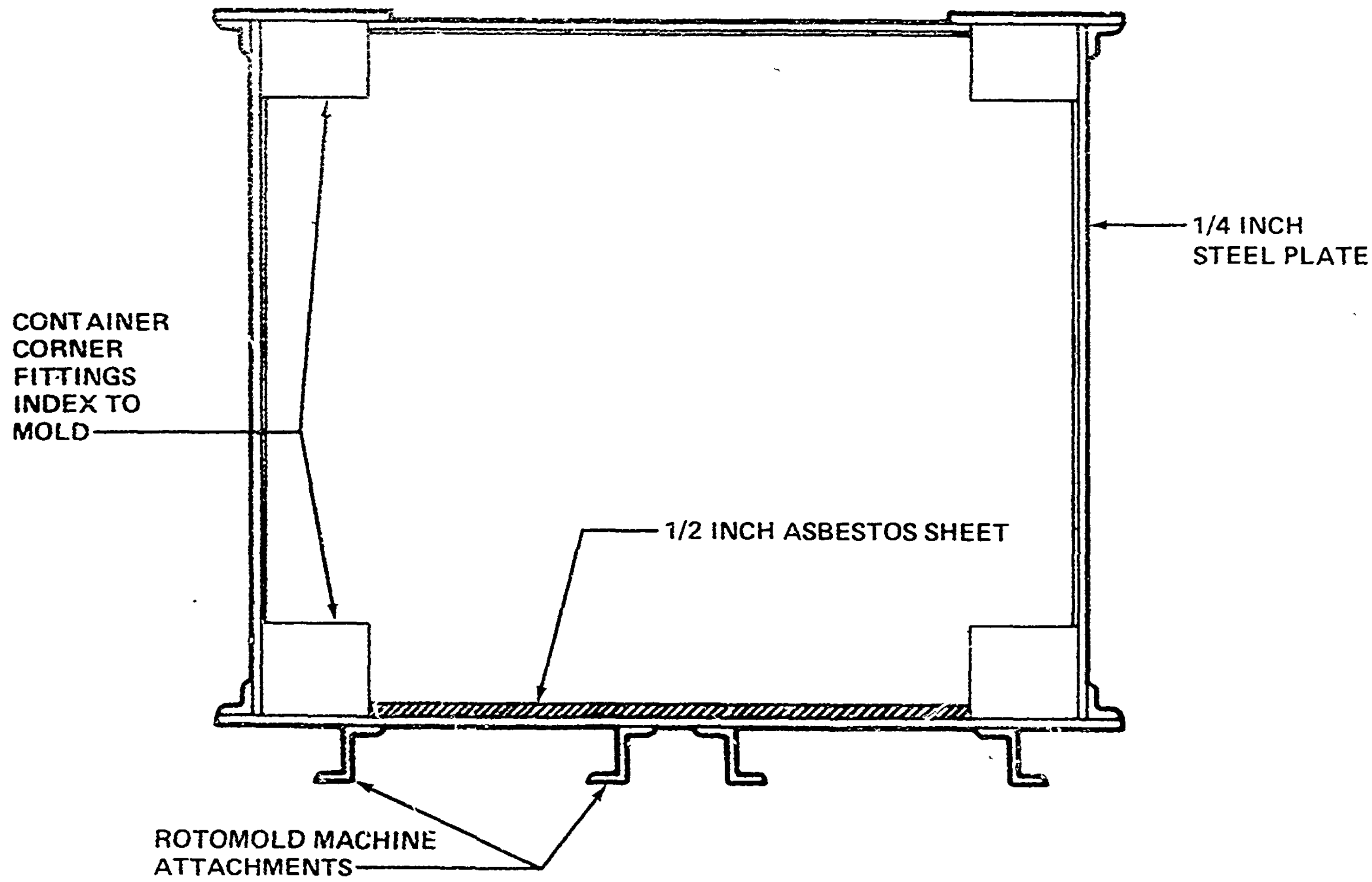


FIGURE 16
.—*SECTION THROUGH STEEL SUBSCALE MOLD*

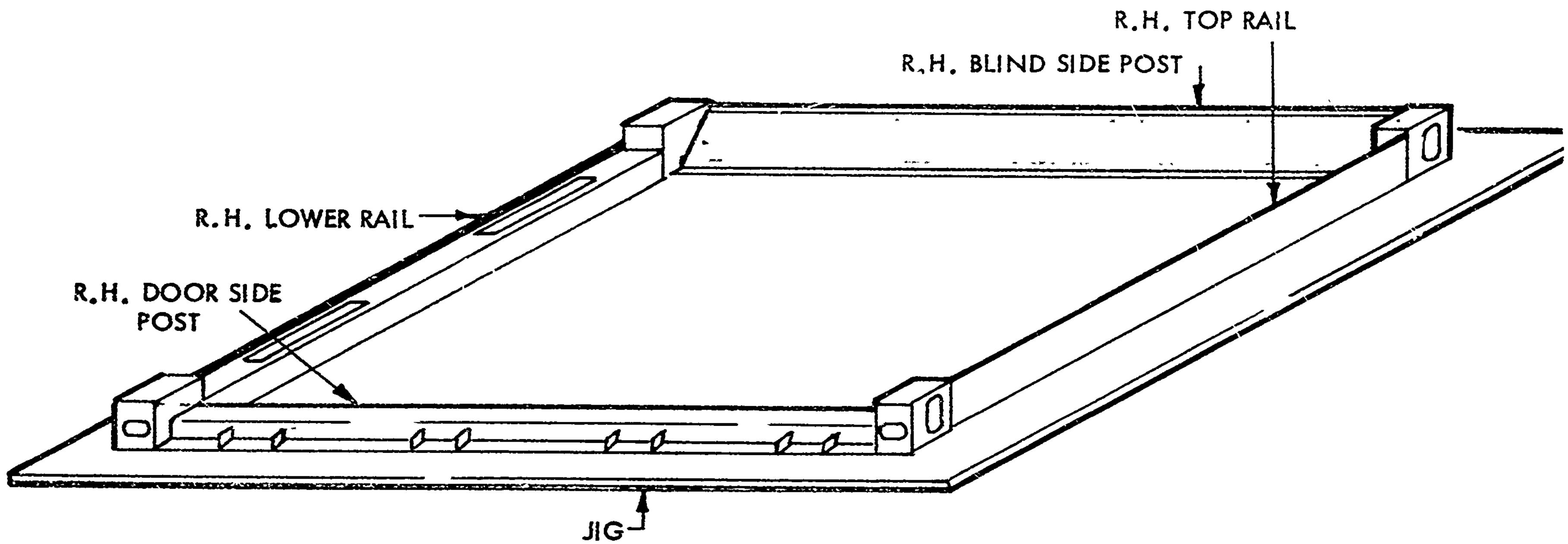


FIGURE 17.

FULL SIZE TRICON FABRICATION SEQUENCE STEP 1 - ASSEMBLE RIGHT AND LEFT HAND END FRAMES

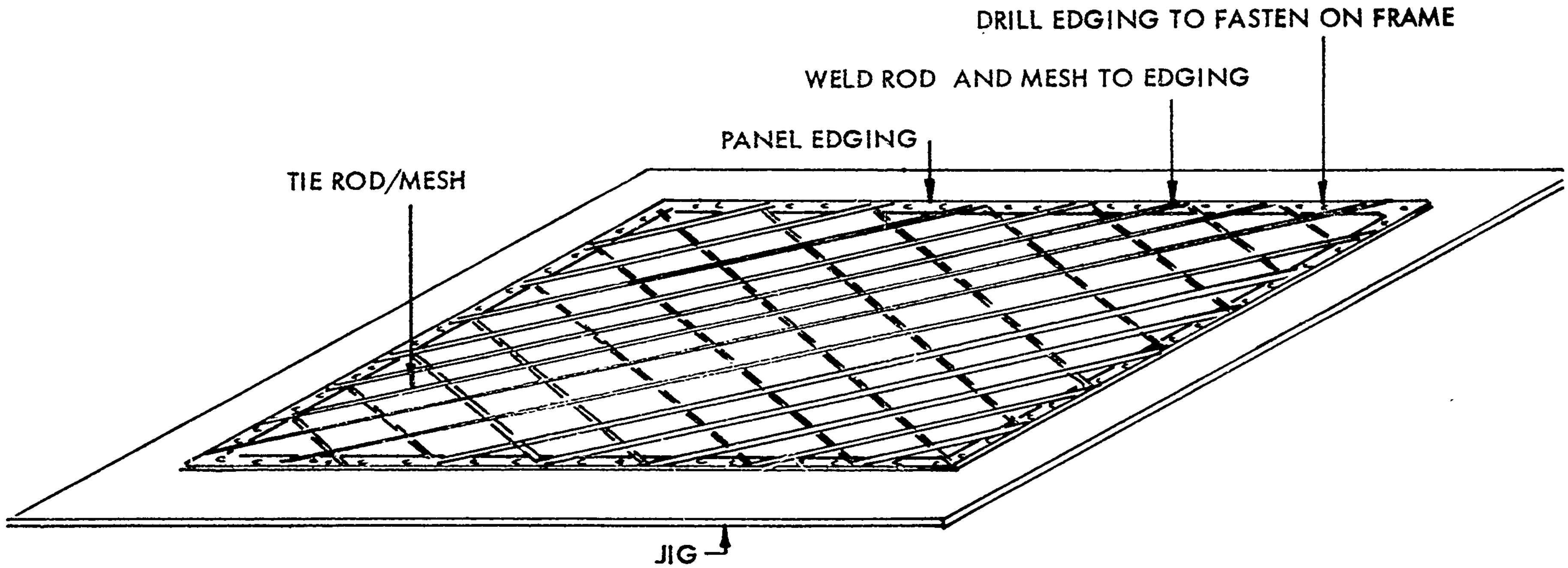


FIGURE 18

FULL SIZE TRICON FABRICATION SEQUENCE
STEP 2 - ASSEMBLE WALL AND ROOF PANELS

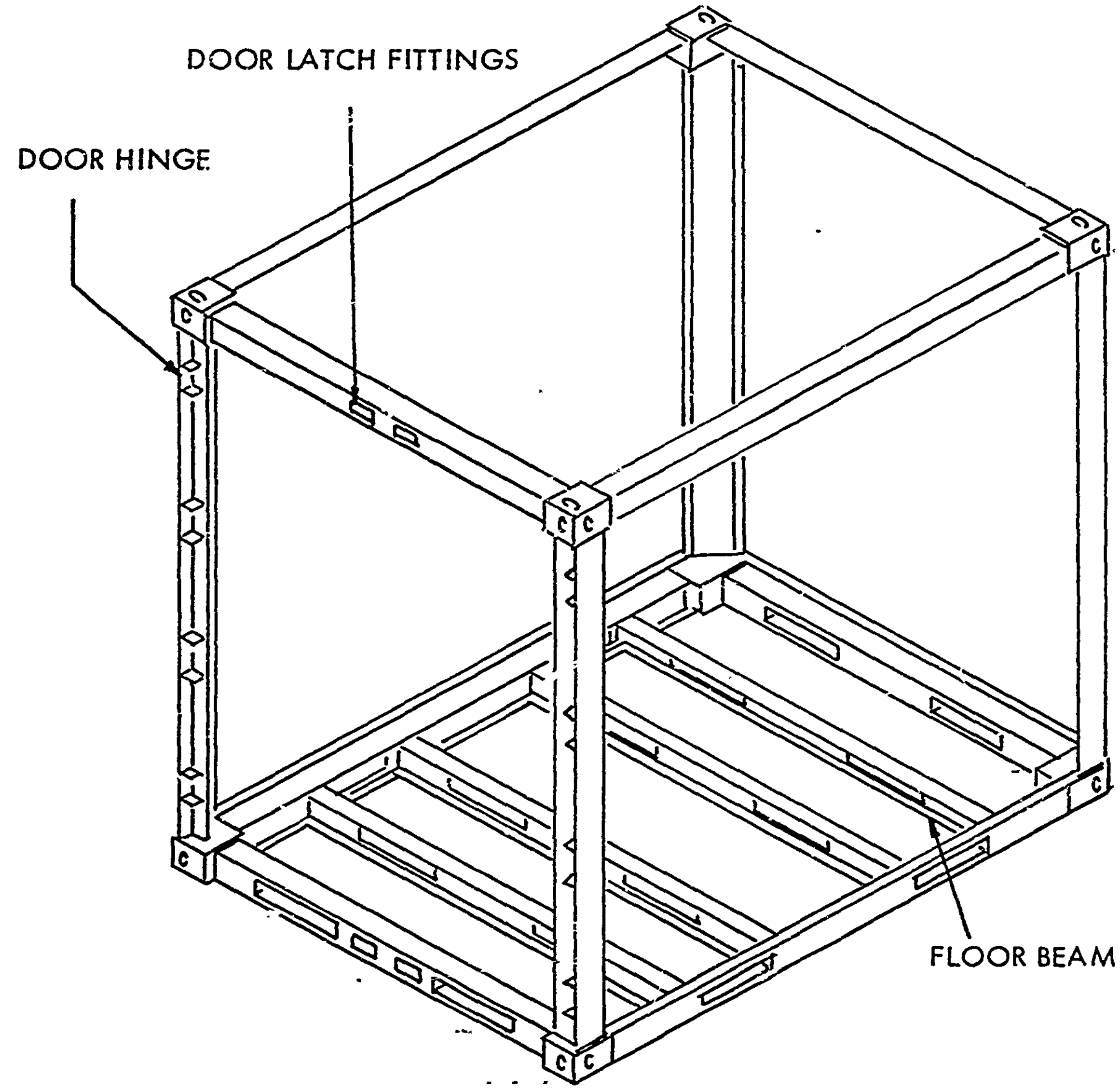


FIGURE 19

FULL SIZE TRICON FABRICATION SEQUENCE
STEP 3 - ASSEMBLE CONTAINER FRAME

Figure 20 – Rivet panels to frame

Figure 21 – Rotomold container, install floor

Figure 22 – Assemble and attach doors

B. Molding Cycle Development

With the selection of crosslinked polyethylene as the plastic material for the TRICON container, a test program was initiated to determine the rotomolding process parameters of this material. It was decided to use pigmented crosslinked polyethylene to eliminate the necessity of painting the container. Since there was a possibility that the addition of pigment to crosslinked polyethylene could significantly affect its molding characteristics, special arrangements were made with the manufacturer, Phillips Petroleum, Bartlettsville, Oklahoma, to compound a special batch of CL-100 crosslinked polyethylene pigmented olive drab, color #X-24087.

When the fabrication of the steel subscale mold was completed, the mold and framework were mounted on the McNeil-Akron Model 1700 Rotocast equipment in the Auburn Production Plastics Shop. A thermocouple study was conducted to determine the time required to bring the framework up to the melting temperature of crosslinked polyethylene. The results are shown in Figure 23.

Additional tests were conducted to establish the time required to build up a sufficient thickness of crosslinked polyethylene to encapsulate the steel framework. It was calculated that the thickness of the plastic should be .25 inch. Tests indicated that 70 minutes at a temperature of 450°F would produce the desired wall thickness.

RIVET WALL PANELS TO FRAME

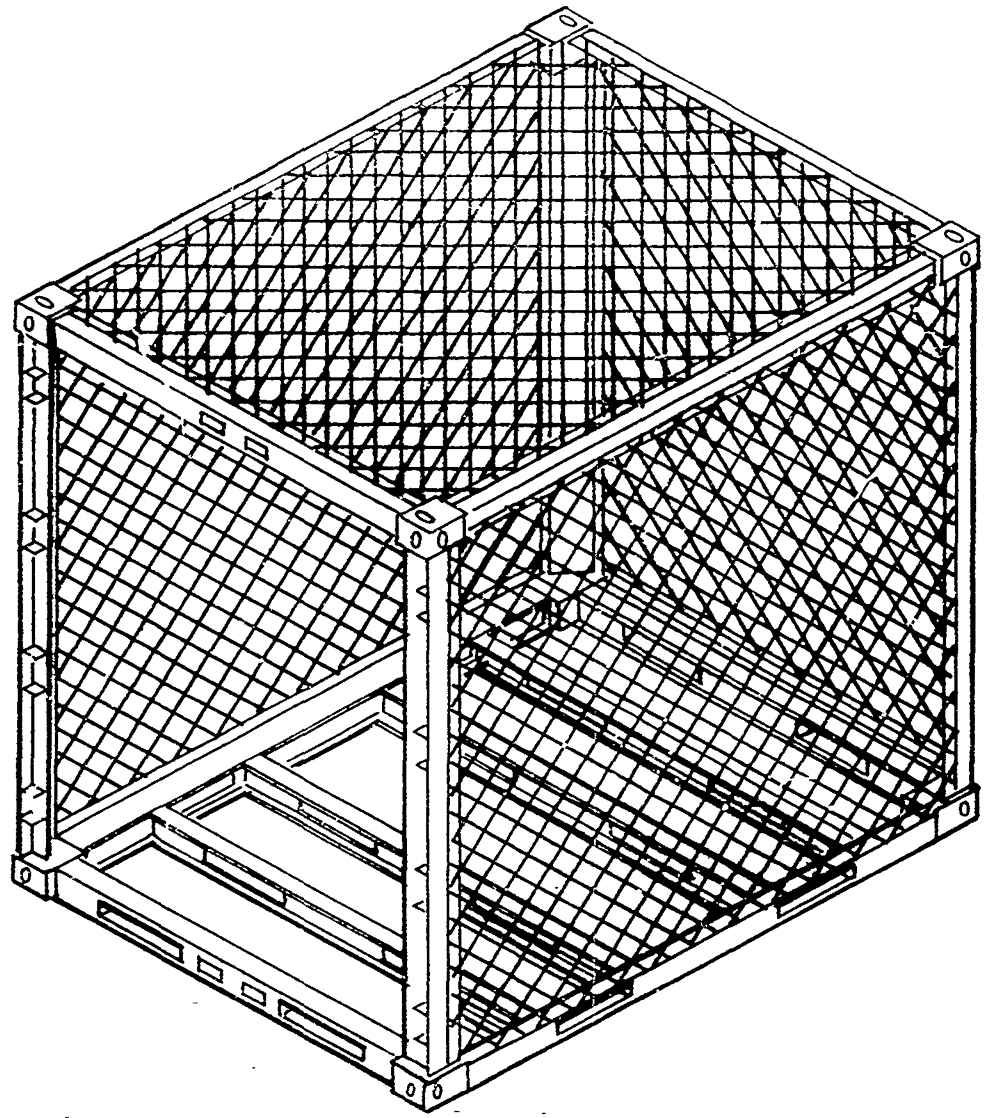


FIGURE 20

FULL SIZE TRICON FABRICATION SEQUENCE
STEP 4 - RIVET WALL PANELS TO FRAME

- ROTOMOLD CONTAINER
- INSTALL WOOD FLOOR

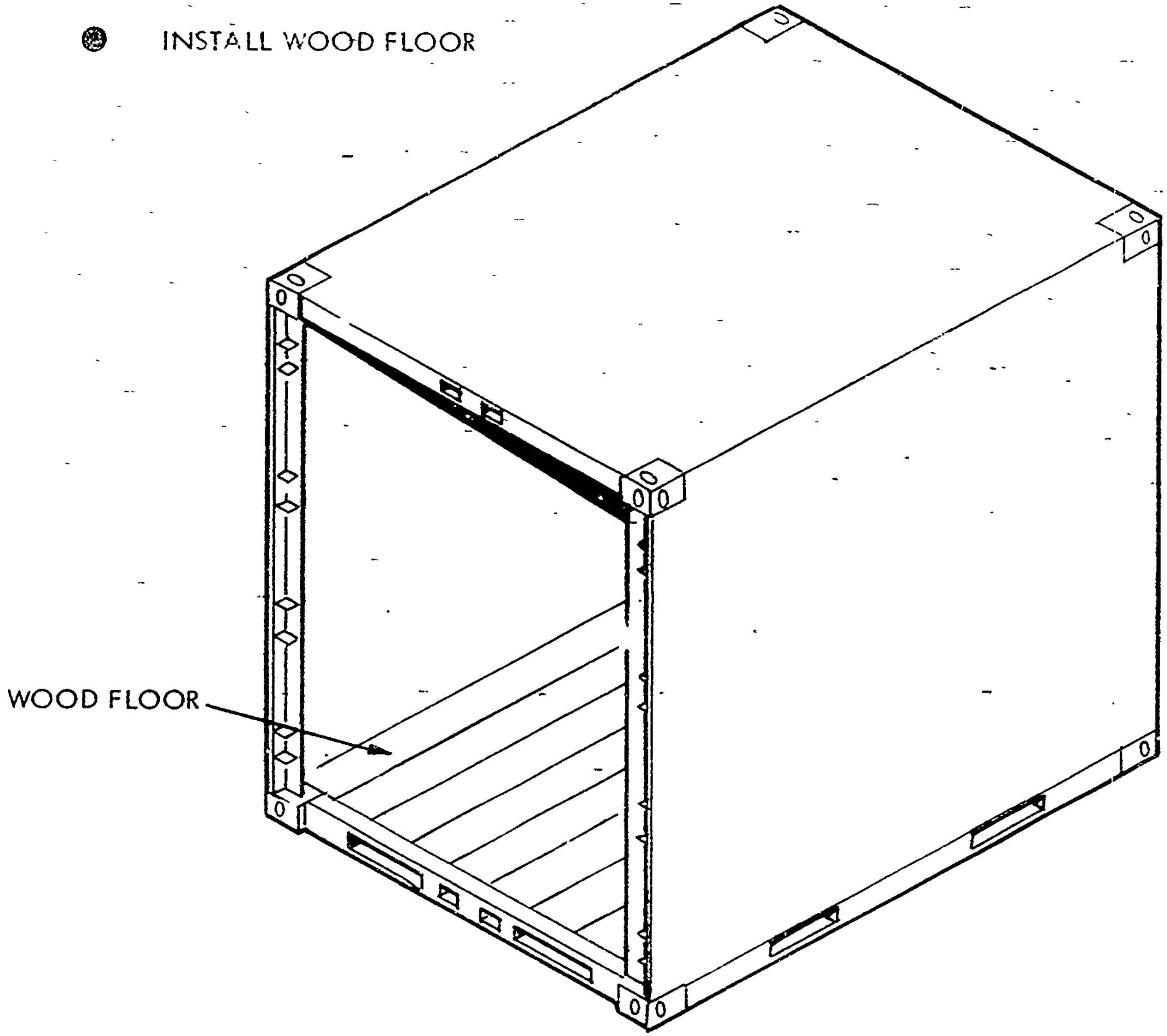


FIGURE 21

FULL SIZE TRICON FABRICATION SEQUENCE
STEP 5 - ROTOMOLD CONTAINER AND INSTALL FLOOR

- ASSEMBLE DOOR FRAME
- ATTACH TIE ROD/MESH
- ROTOMOLD DOORS

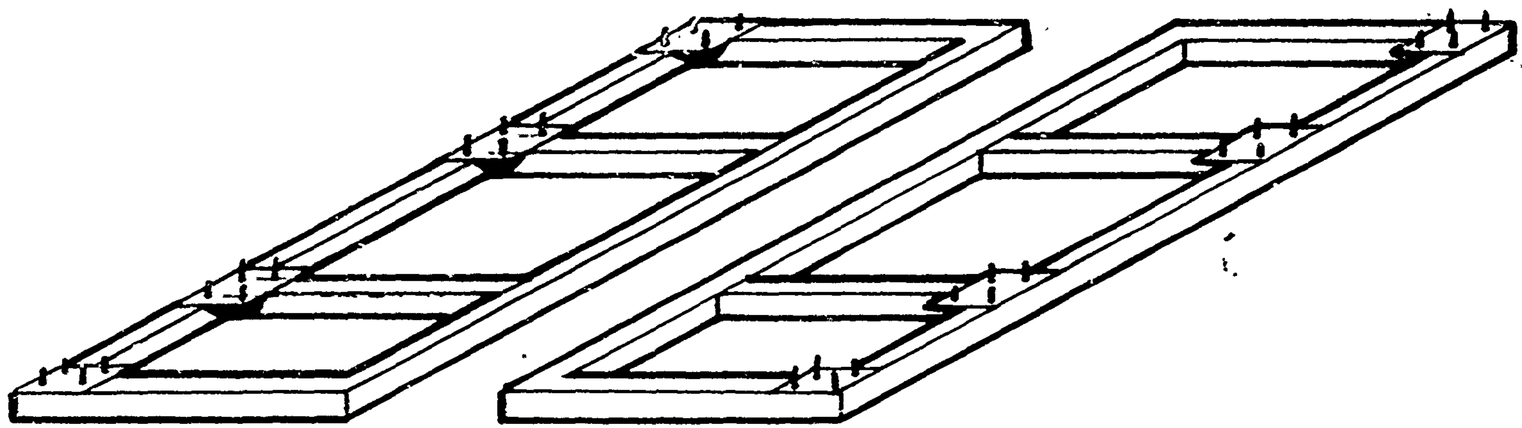
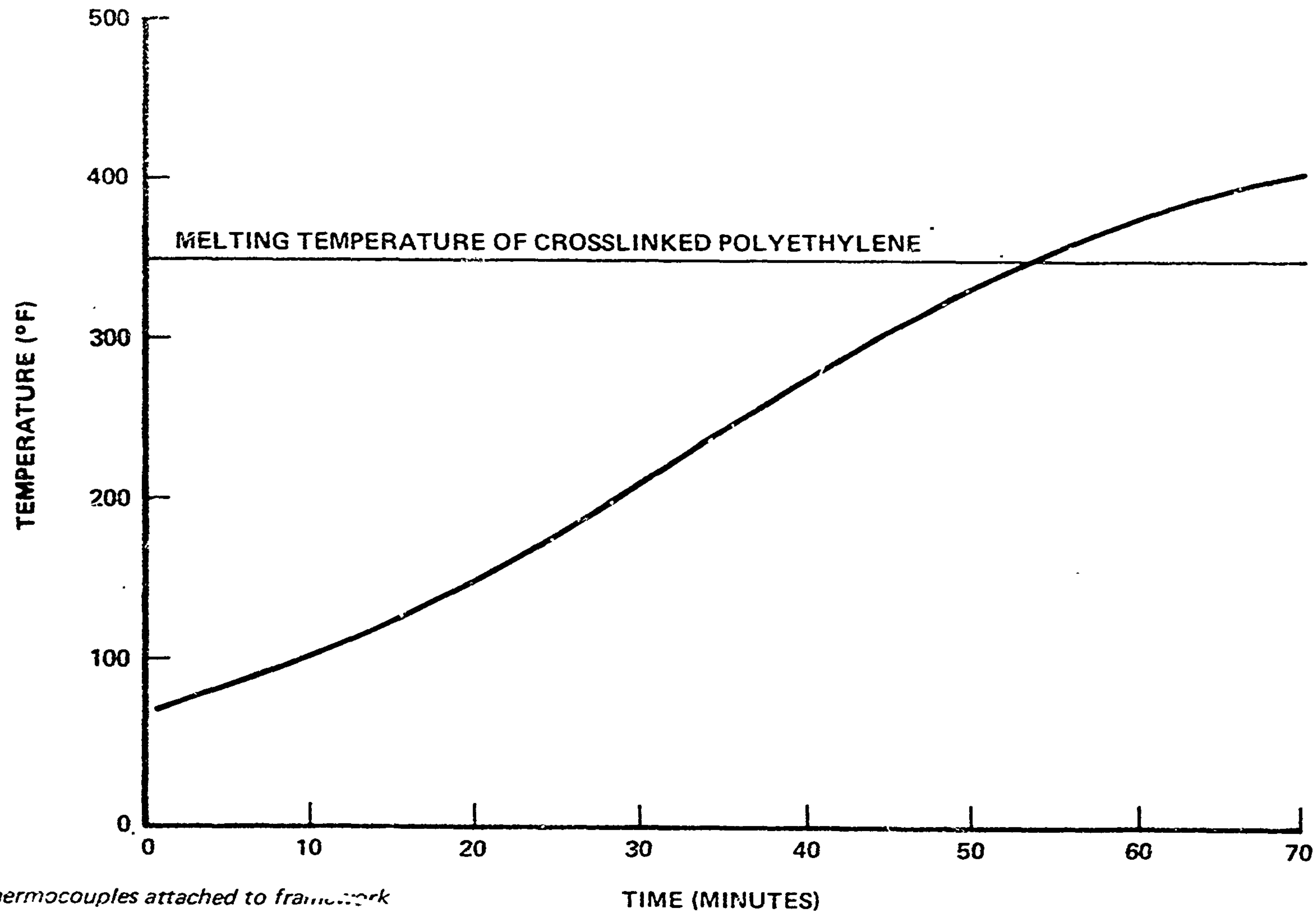


FIGURE 22

FULL SIZE TRICON FABRICATION SEQUENCE
STEP 6 - ASSEMBLE AND ATTACH DOORS



*Thermocouples attached to framework

FIGURE 23
—THERMOCOUPLE STUDY ON SUBSCALE MOLD AND FRAMEWORK*

3.2.4 Molding of Subscale Containers

A. Molding Sequence

Two subscale containers were rotational molded in the following manner:

1. The steel framework was positioned inside the steel mold (see Figures 24 and 25). The corner fittings served to index the framework and secure it during the molding cycle. The framework side panels were positioned approximately 1/4 inch inside the mold wall.

2. A charge of olive drab crosslinked polyethylene was placed inside the mold (see Figure 26).

3. The assembly was then placed inside the oven and heated for 50 minutes until it reached a temperature of 350°F ± 10°F (see Figure 27).

4. The temperature was then raised to 450°F ± 10°F and the entire assembly rotated for 70 minutes. The rotation settings were 11 rpm on the minor axis, and 7-1/2 rpm on the major axis.

5. The entire assembly was placed in the cooling chamber of the rotocast equipment and quenched with cold water for 20 minutes.

B. Inspection Results

The two rotomolded containers (see Figure 28) were closely inspected. The following observations and analyses were made:

1. The first subscale container exhibited poor bond between the steel and the crosslinked polyethylene in localized areas. It was felt that the prolonged heating cycle caused oxidation of the steel, resulting in a poor bonding surface for the crosslinked polyethylene. During molding of the second subscale container, nitrogen was introduced into the mold cavity. No visible improvements in the metal-to-plastic bond was noted.

2. The sidewall panel consisting of expanded steel and the panel consisting of punched steel plate encapsulated satisfactorily.

FIGURE 24

STEEL FRAMEWORK FOR SUBSCALE CONTAINER

FIGURE 25

STEEL FRAMEWORK FOR SUBSCALE CONTAINER
INDEXED INSIDE MOLD

FIGURE 26

MOLD CHARGED WITH ROTATIONAL MOLDING
GRADE CROSSLINKED POLYETHYLENE

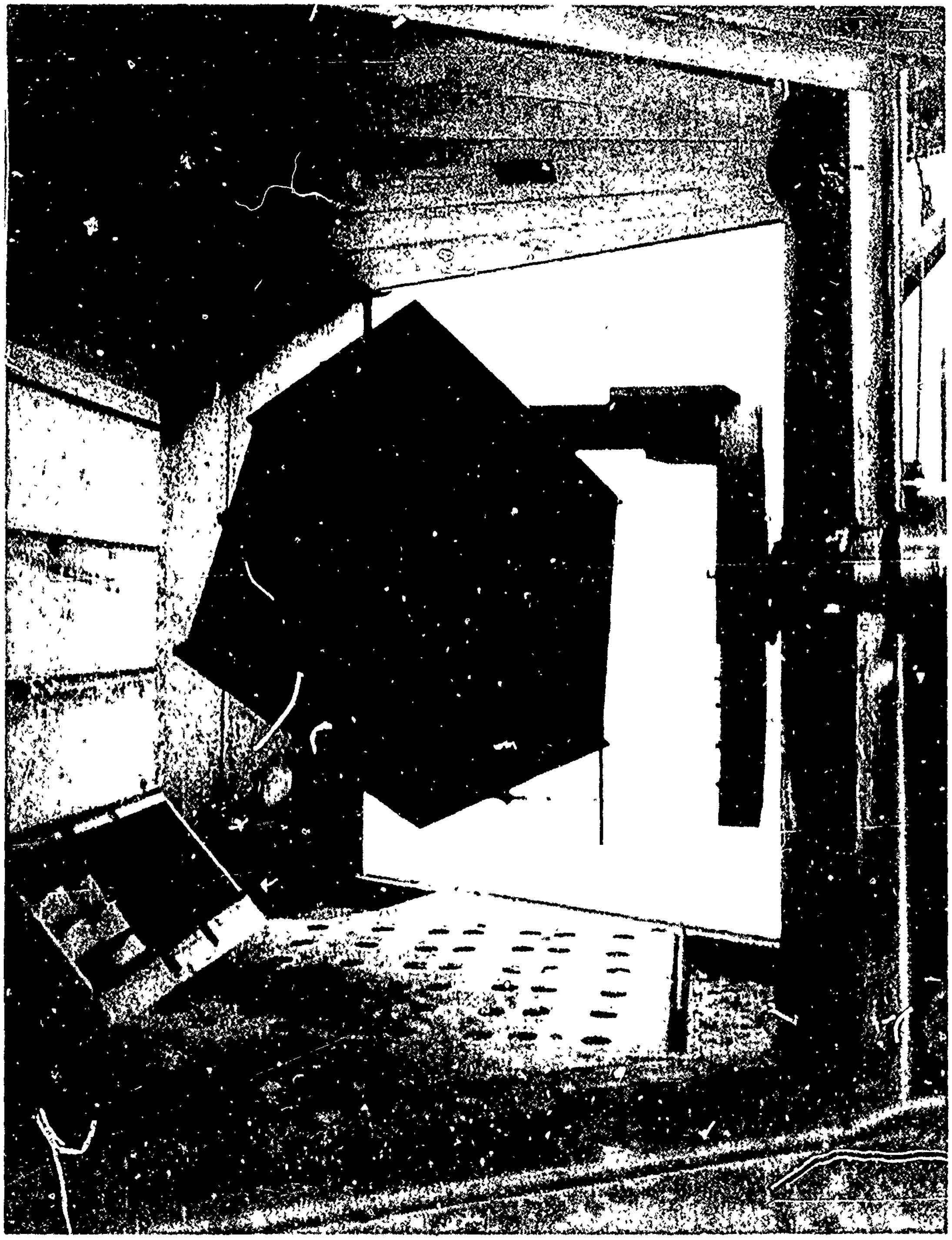


FIGURE 27

SUBSCALE CONTAINER MOLD ROTATING IN HEATING CHAMBER
OF McNEIL-AKRON MODEL 1700 ROTOCAST EQUIPMENT

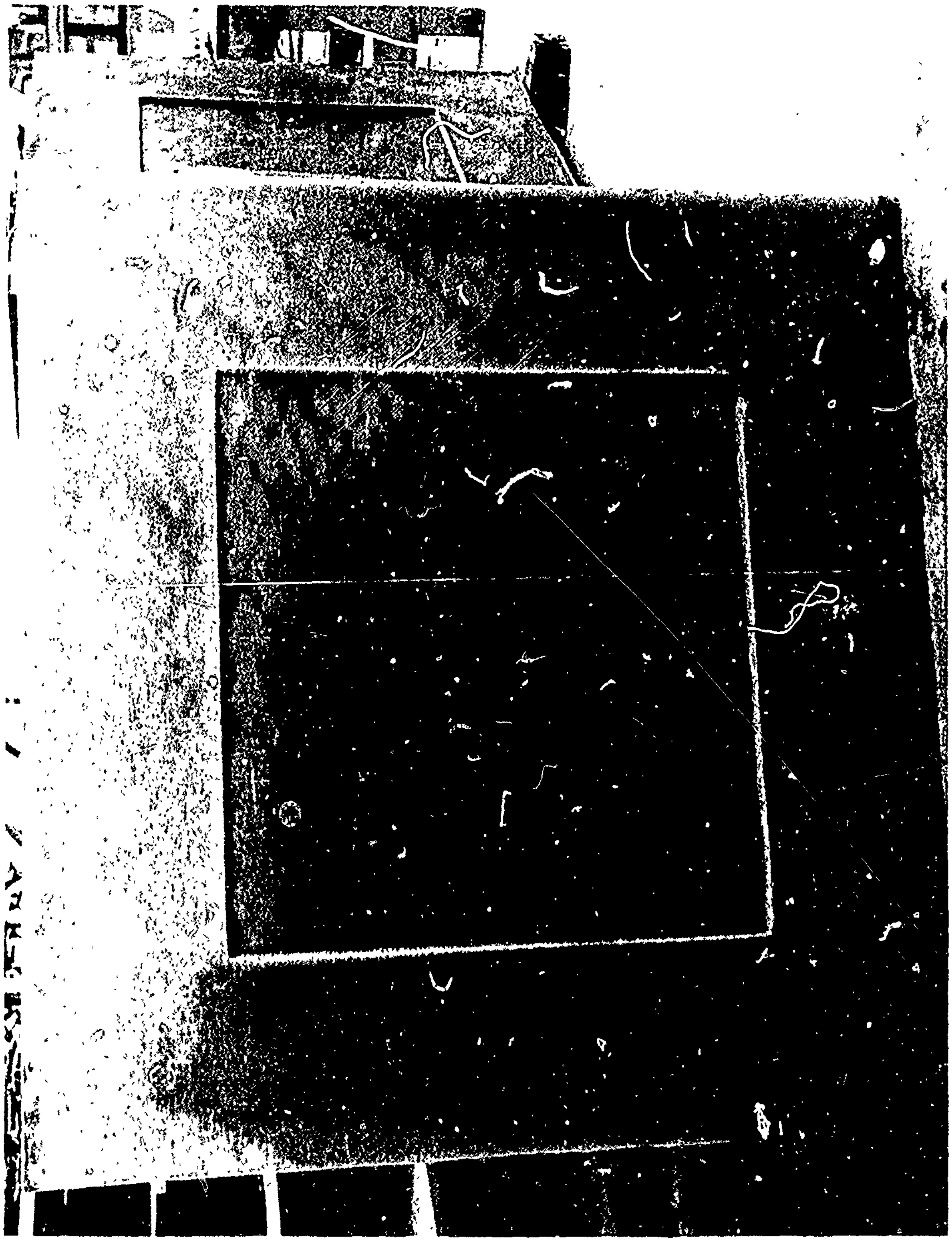


FIGURE 28

TWO SUBSCALE CONTAINERS (STEEL FRAMEWORK)
ENCAPSULATED IN CROSSLINKED POLYETHYLENE

3. The sidewall panels consisting of expanded steel and welded tie rods did not encapsulate. The poor results were attributed to the distance between the expanded metal and the tie rods being too great to allow the formation of a homogeneous plastic skin.

The third subscale container was molded using the same processing cycle utilized in the molding of the second subscale container. The results were similar to the results of the initial subscale container molding, except that the metal-to-plastic bond was slightly improved.

A fourth and final subscale container was molded. The framework was sandblasted prior to molding. The sidewall panels consisted of various patterns of expanded metal and punched plate. The panels utilizing tie rods were eliminated from the fourth subscale framework design. The molding cycle employed on the three previous subscale containers was utilizing in molding the fourth subscale container. The fourth subscale container exhibited a uniform coating on all of the sidewall panels. The metal-to-plastic bond appeared superior to the first three subscale containers.

3.2.5 Engineering Analysis

The purpose of the Engineering analysis was to conduct a thorough review of the program results to date and make decisions influencing future activity on the program, particularly with respect to materials, design, and process parameters.

Panels were cut from the subscale containers and tested. The test results are summarized in Figure 29.

After an analysis of the results of molding the four subscale container, the following conclusions were reached:

TEST	TEST RESULT
Flammability	Self-extinguishing (burn rate of less than one inch per minute)
Weatherometer	No effect
Skydrol Immersion (130^{o}F for 24 hours)	No deleterious effects
Tensile Strength	1500 psi
Flexural Modulus	100,000 psi

FIGURE 29

TESTS CONDUCTED ON SECTIONS CUT FROM ROTO-MOLDED SUBSCALE CONTAINER SIDEWALL PANELS

1. Sidewall panel design would be either punched plate or expanded metal.

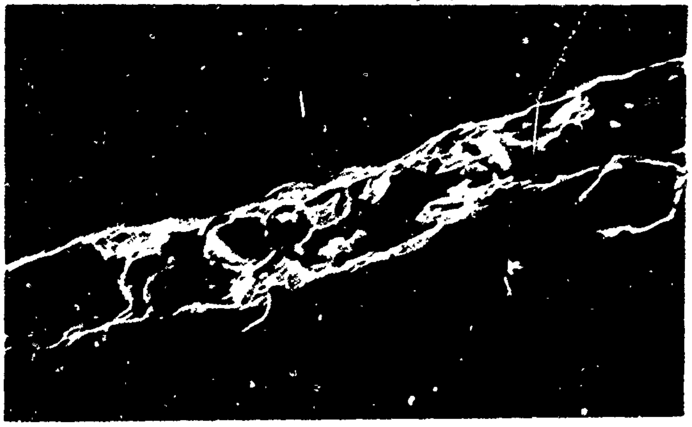
2. An attempt would be made during design of the full size TRICON container to eliminate some of the mass from the corner posts and spread it more uniformly throughout the framework. It was felt that this would eliminate a potential heat sink that might create cool down problems during rotomolding of the full size TRICON.

3.3 REDESIGN OF SUBSCALE CONTAINER AND MOLD

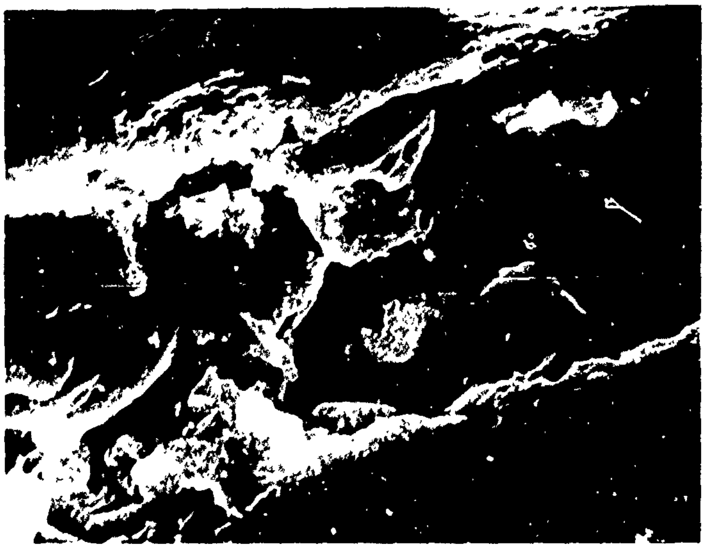
Approximately two months after molding the subscale containers, it was observed that stress cracks were beginning to appear in the encapsulating plastic. Close visual inspection revealed that, upon aging, the plastic had developed cracks up to 1-1/4 inches in length and 1/16 inch in depth on both the inner and outer surfaces of the subscale container walls. When the subscale containers were initially molded, no signs of stress cracks were visible. Furthermore, the containers were subjected to severe impact at the time they were molded with no sign of failure.

In order to determine the exact nature of the cracks and develop clues as to their cause, a series of microphotographs were taken (see Figure 30). These photographs showed that the cracks were randomly distributed and were not aligned with any single axis. However, close examination of the microphotographs led to the conclusion that the cracks were caused by tensile stress in the plastic material related to the nominal shrinkage of the crosslinked polyethylene.

It is a recognized fact in molding of thermoplastics that cooling rates have an affect on nominal shrinkage of the thermoplastic material being molded. In general, the slower the cooling rate, the greater the shrinkage. When the sub-



400X SURFACE CRACK ABOUT 1/2 INCH LONG AND 0.001 INCH WIDE



1600X SURFACE CRACK ABOUT 1/2 INCH LONG AND 0.001 INCH WIDE

6X SURFACE CRACKS WHITE SPOTS ARE PIGMENTED POLYETHELYENE

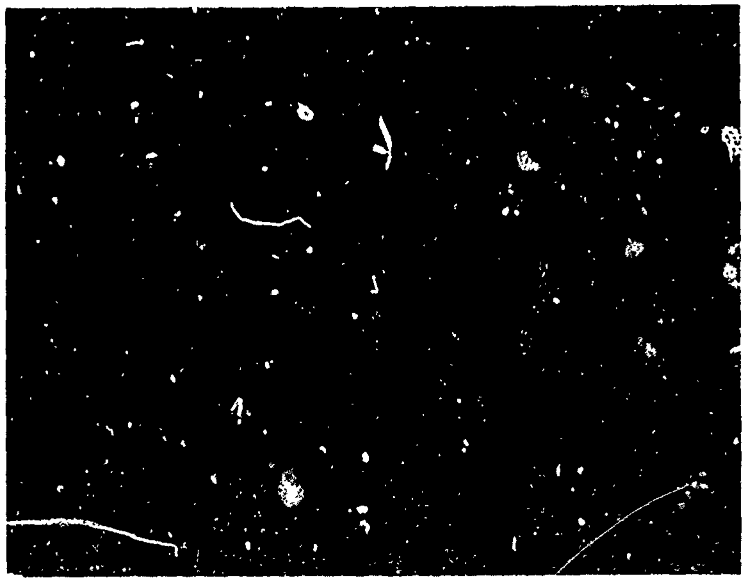


FIGURE 30

SURFACE CRACKS IN CROSSLINKED POLYETHYLENE SUBSCALE CONTAINER SIDEWALL

scale containers were molded, the relatively large mass of metal in the framework behaved as a heat sink during the molding cycle. While a cooling period of 5-7 minutes had been anticipated, the actual cool down time was 20 minutes. It was thought that this slow cool down rate increased the shrinkage of the plastic and contributed to the stress crack by increasing the nominal shrinkage beyond what had been anticipated.

A contract amendment was issued by USAMERDC to provide for:

1. Addition of redesign of subscale container and mold.
2. Molding of an additional subscale container.
3. Expansion of process optimization phase to solve stress cracking problems.
4. Reduction of contract terms from the fabrication of six full size TRICON containers to three containers.

Boeing proposed to resolve the problem by reducing the shrinkage of the plastic with (a) the addition of glass fibers and/or (b) reducing the cooling time. To this end, the following specific tasks were undertaken:

1. A redesign of the subscale container to (a) reduce the mass of the metal framework and (b) change from steel to aluminum for better heat conductivity.

2. The initiation of a series of tests to determine the feasibility of modifying the plastic with glass fibers to decrease the nominal shrinkage.

3. Molding tests to determine the optimum percentage of glass fibers to reduce shrinkage while still encapsulating the metal reinforcement.

4. A test program to determine the minimum allowable cooling rate.

5. Rotational molding of at least one additional subscale container.

The results of these tests led to the decision that the molding of the subscale container would be carried out using the following process parameters:

1. Bringing the mold and metal reinforcement to 350°F, a temperature just under the molding temperature of the crosslinked polyethylene.

2. Rotating the assembly at 450°F for 70 minutes, using a rotation of 7-1/2 rpm on the major axis and 11 rpm on the minor axis.

3. A water cooling cycle of 20 minutes duration.

Using the cycle described above, a subscale container without the metal reinforcement was successfully molded. Sections were cut from the molded shell, and it was determined that the wall thickness through the part was .25 inch ± .015 inch.

3.3.1 Materials Study

A materials study was initiated to determine the effect of certain process variables on the nominal shrinkage of various thermoplastic materials. The following tests were conducted:

- Determination of the effect of fiberglass filler on nominal shrinkage of various thermoplastics.
- Determination of the effect of cooling rate on the nominal shrinkage of various thermoplastics.
- Determination of the effect of fiberglass filler on the molding characteristics of rotomolded crosslinkable polyethylene and linear polyethylene.

A. Effect of Fiberglass Filler on Shrinkage

The determination of the effect of the addition of various percentages of chopped fiberglass on the nominal shrinkage of the rotational molding grade powder was accomplished by the actual molding of parts in a mold approximately 12 by 12 by 10 inch inside dimension. The wall thickness of the molded parts was approximately .25 inch.

Before shrinkage versus percent fiberglass information could be generated, it was necessary to evaluate various fiberglass materials and develop techniques for rotational molding parts with plastic-fiberglass blends. Consultations with various materials suppliers revealed that this capability did not exist in the rotational molding industry. Further, there was no generated data that could be used as a starting point for our efforts.

It was decided to evaluate blends of crosslinked polyethylene and the following materials; milled glass fibers, 1/8" chopped fiberglass strands, and 1/16 inch chopped fiberglass strands. The fiberglass was blended with the crosslinked polyethylene by placing the desired proportions of each component in a drum and rotating the drum on a drum roller. It was found that the most uniform dispersion of the fiberglass was achieved when the drum was filled to only about 1/3 of its volume capacity.

Molding attempts were first made with a blend of crosslinked polyethylene and milled glass fibers. It was found that the milled glass fibers balled together during the rotational molding cycle, creating lumps of incompletely wetted milled glass fibers on the inside wall of the part. Molding attempts with a blend of crosslinked polyethylene and 1/16 inch chopped fiberglass strands produced similar results.

Success was achieved when parts were molded with a blend of crosslinked polyethylene and 1/8 inch chopped fiberglass strands. The outer surface of the part exhibited a good surface finish which was an accurate image of the mold surface. The 1/8 inch chopped fiberglass strands were thoroughly wetted and were dispersed uniformly throughout the part.

Based on this experience, the shrinkage versus percent fiberglass test data was generated using a blend of 1/8 inch chopped fiberglass strand and CL-100 crosslinked polyethylene.

The tests were conducted in the following manner:

1. Lines were scribed exactly ten inches apart on the two 12 by 12 inch walls.

2. Release agent was applied to the mold.

3. The fiberglass filler (1/8-inch fiberglass strands) and plastic powder were carefully weighed in the proper proportions and blended together by tumbling on a drum roller.

4. A charge of the blend, sufficient to produce a part with a .25 inch wall, was placed inside the mold.

5. The part was rotational molded using the cycle recommended by the material manufacturer, and cooled to 150°F in 5 minutes.

6. The part was removed from the mold, allowed to stand at room temperature for 24 hours, and the distance between the scribe lines on the part measured.

The nominal shrinkage was calculated using the following formula:

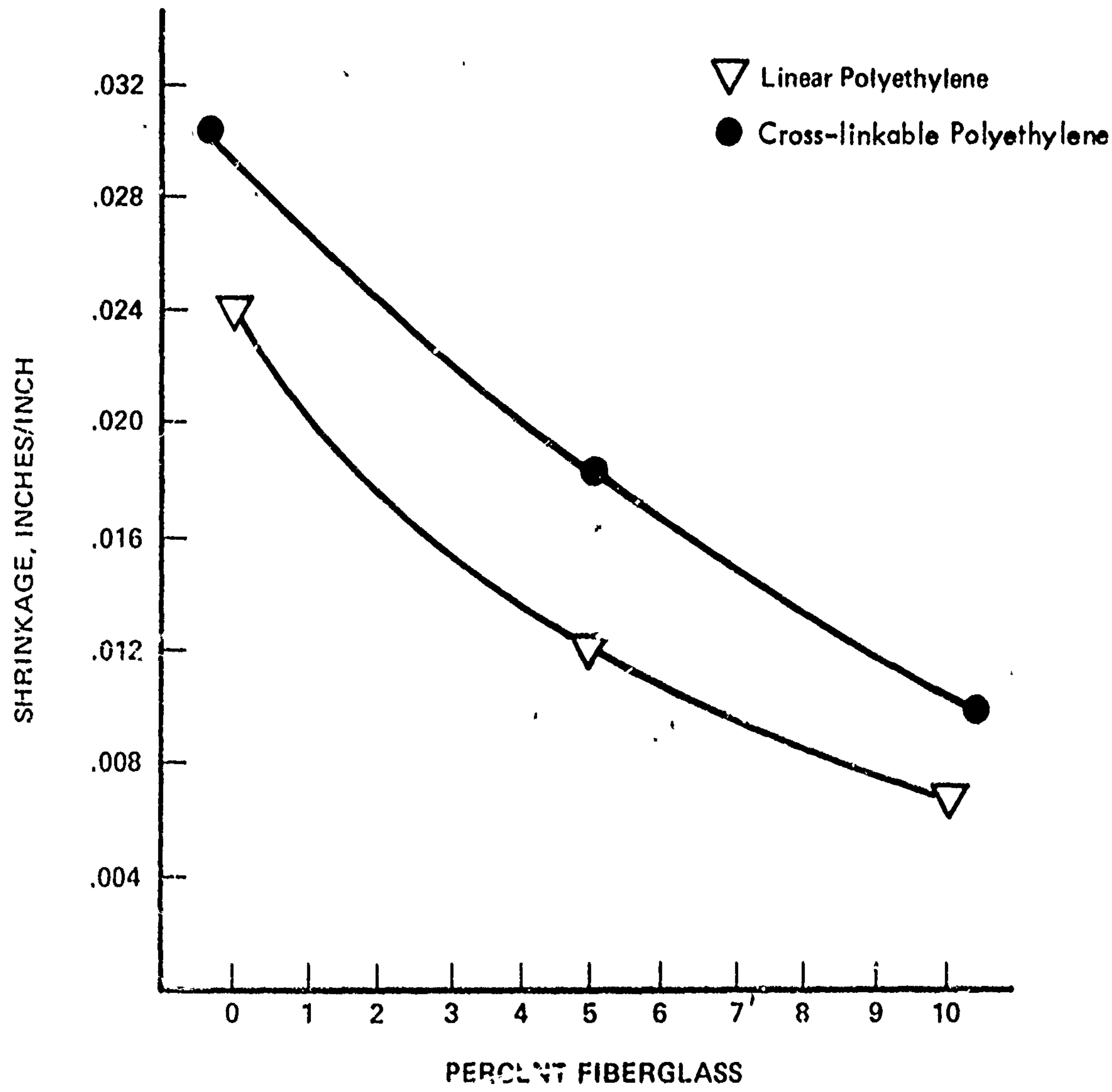
$$\text{Nominal Shrinkage (inches/inch)} = \frac{10 - d}{10}$$

where d = distance between the scribe lines on the part.

These tests were conducted with both crosslinked polyethylene and linear polyethylene. The results (Figure 31) show that the addition of fiberglass filler significantly reduces the nominal shrinkage of the rotomolded plastic.

B. <u>Effect of Cooling Rate on Shrinkage</u>

A series of tests was conducted to establish the relationship between cooling rate and nominal shrinkage. Data was generated on crosslinked polyethylene with and without fiberglass filler and on linear polyethylene with and without fiberglass filler.



*Cooled from 700° F to 150° F in 5 Minutes

FIGURE 31

–EFFECT OF FIBERGLASS FILLER ON SHRINKAGE OF VARIOUS ROTOMOLDED THERMOPLASTICS*

The tests were conducted as follows, using the same mold to conduct the shrinkage - percentage filler tests:

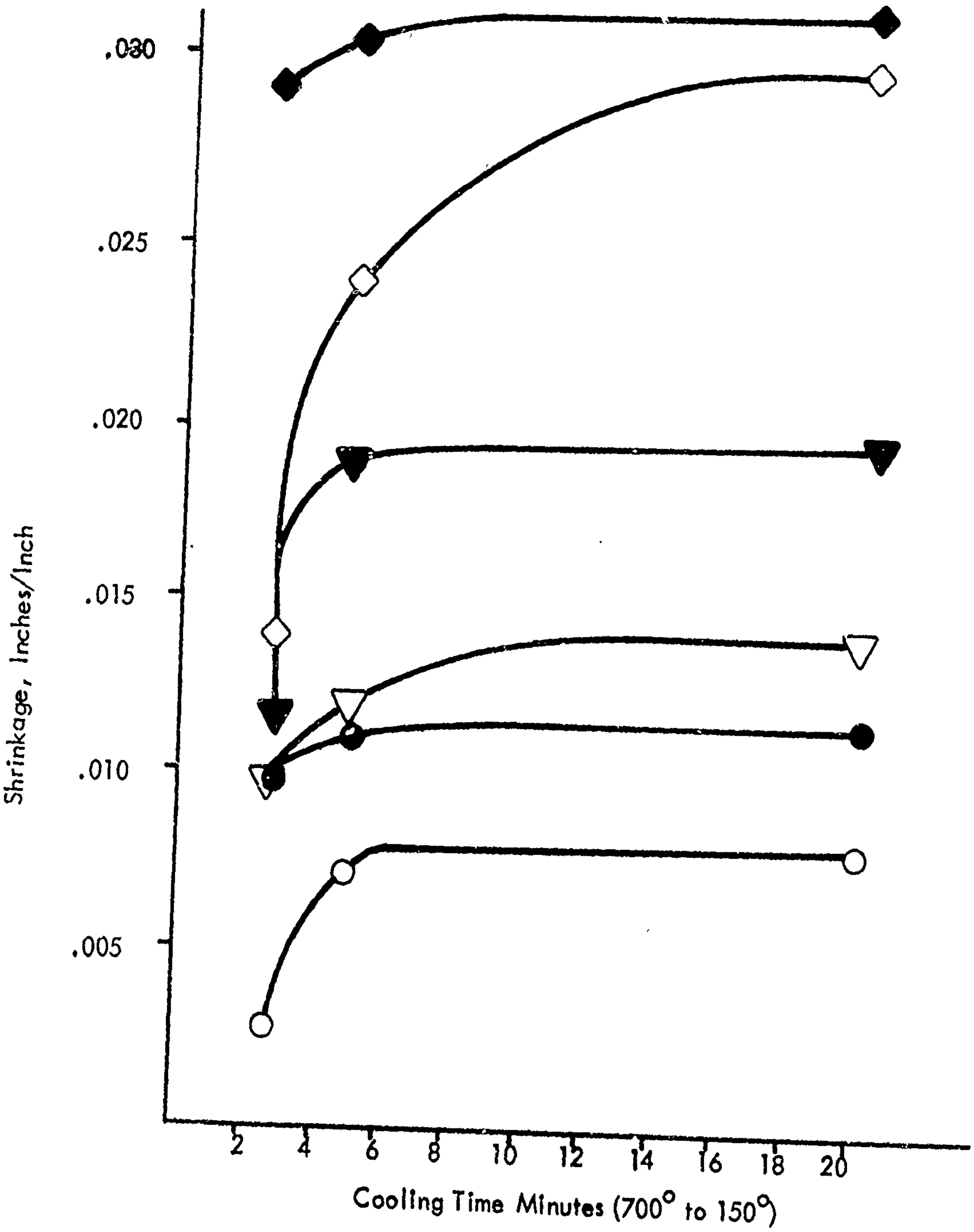
1. The charge of plastic was placed inside the mold.
2. The part was molded using the time and temperature recommended by the material supplier.
3. The time required to cool the part to 150°F was varied from 2 minutes to 20 minutes.
4. The part was removed from the mold and allowed to stand for 24 hours at room temperature.
5. The distance between the scribe marks on the part was measured.
6. Nominal shrinkage was calculated in the same manner used in the preceeding tests.

The test results showed that a decrease in cooling time results in a reduction of the shrinkage of the rotomolded plastic (Figure 32). The data also indicates that the cooling time must be less than four minutes before the reduction of shrinkage is significant.

It would obviously be impossible to cool the mass of metal in the full size TRICON framework to 150°F within 4 minutes with conventional rotational molding equipment. It was concluded at this point that future efforts to reduce shrinkage would be directed toward the addition of fiberglass filler, since that approach appeared to offer the greatest likelihood of success.

C. Effect of Fiberglass Filler on Molding Characteristics

These tests were conducted for the purpose of determining the feasibility of encapsulating the metal framework of the TRICON container with blends of thermoplastic and 1/8-inch chopped fiberglass strands. Studies were made with both a simulated sidewall panel and simulated corner post.



LEGEND:
- ◆ Cross Linkable Polyethylene
- ▼ Cross Linkable Polyethylene with 5% Glass
- ● Cross Linkable Polyethylene with 10% Glass
- ◇ Linear Polyethylene (DYLAN 5440)
- ▽ Linear Polyethylene with 5% F/G
- ○ Linear Polyethylene with 10% F/G

FIGURE 32

EFFECT OF COOLING RATE ON SHRINKAGE OF ROTOMOLDED THERMOPLASTICS

A secondary objective of these tests was to determine the maximum percentage of fiberglass filler that could be added to the thermoplastic and still permit complete encapsulation of the metal framework.

1. <u>Test #1 - Simulated Sidewall Encapsulation</u>

   An 8 by 8 inch piece of 3/4-inch, #12 expanded aluminum was positioned .13 inch away from the flat inside wall of a rotational mold. The mold was charged with plastic and various plastic-chopped fiberglass blends. The parts were rotomolded and removed from the mold upon cooling. The top of the hollow cube thus formed was removed and the samples were visually inspected for degree of encapsulation and overall quality and appearance. The test results are shown in Figure 33.

2. <u>Test #2 - Simulated Corner Post Encapsulation</u>

   An aluminum angle, four inches in width, was positioned .13 inch away from the corner of the mold. Parts were made with crosslinked polyethylene, linear polyethylene, and various blends of these materials and 1/8-inch chopped fiberglass strands. The parts were rotational molded and removed from the mold upon cooling. The top of the molded hollow cube was cut off, and the part was inspected for degree of encapsulation, overall quality, and appearance. The test results are shown in Figure 34.

   The results of these tests proved that, with present technology, it was not possible to encapsulate the TRICON framework with cross-linked polyethylene blended with a sufficient amount of chopped fiberglass strands to reduce the nominal shrinkage of the plastic.

   The results of the materials study were reported to USAMERDC. The following course of action was decided upon:

MATERIAL	PERCENT 1/8 INCH CHOPPED FIBERGLASS STRANDS, BY WEIGHT	RESULT
Crosslinked Polyethylene	0	Good encapsulation (some small pinholes)
Crosslinked Polyethylene	2	Incomplete encapsulation
Crosslinked Polyethylene	5	Poor encapsulation and poor wetting of glass fibers
Linear Polyethylene	0	Good encapsulation (some small pinholes)
Linear Polyethylene	2	Incomplete encapsulation
Linear Polyethylene	5	Poor encapsulation and poor wetting of glass fibers

FIGURE 33

ENCAPSULATION OF SIMULATED SIDEWALL PANEL WITH VARIOUS THERMOPLASTIC-CHOPPED FIBERGLASS BLENDS

MATERIAL	PERCENT 1/8 INCH CHOPPED FIBERGLASS STRANDS, BY WEIGHT	RESULT
Crosslinked Polyethylene	0	Fair encapsulation (some bridging)
Crosslinked Polyethylene	2	Poor encapsulation
Crosslinked Polyethylene	5	Very poor encapsulation and poor wetting of glass fibers
Linear Polyethylene	0	Fair encapsulation with some bridging
Linear Polyethylene	2	Poor encapsulation
Linear Polyethylene	5	Poor encapsulation and poor wetting of glass fibers

FIGURE 34

ENCAPSULATION OF SIMULATED CORNER POST WITH VARIOUS THERMOPLASTIC-CHOPPED FIBERGLASS BLENDS

a. Continue full size TRICON container design.

b. Continue full size mold design.

c. Conduct a process optimization study to overcome the stress cracking problem.

3.3.2 Redesign of Subscale Container

Because of unsatisfactory test results with the steel rotomolded substructure, described in the previous section, a decision was made to design and build an all-aluminum subscale frame for further process feasibility evaluation. It had been established that in order to successfully encapsulate the metal structure, rapid heatup and cool down rates during the molding cycle were mandatory to prevent development of stress cracks in the plastic matrix. The selection of aluminum rather than steel for the structural material was, therefore, expected to improve the encapsulation process based on its inherent mass reduction as well as the substantial increase in thermal conductivity. Further benefits of a change to aluminum were (1) an obvious total container weight reduction and (2) an improved adherence of the plastic to the base metal. As pointed out in Section 3.2 of this report, the high molding temperatures of the plastic limit the selection of aluminum alloy to Al. 2219-T87, provided efficient structural design is to be maintained. Most all other aluminum alloys undergo too drastic a strength reduction after exposure to the molding heat cycle. See Figure 12 for typical material property comparisons. It was learned from material suppliers that 2219 aluminum alloy was not stocked locally and required a long delivery time on small orders. Therefore, it was decided to fabricate the first prototype aluminum subscale container from readily available Al 6061 in order to maintain contract schedule. This selection was justified because the purpose of the first test container was to establish feasibility of the rotomolding process, rather than structural integrity.

During this phase of the program tests were conducted with aluminum perforated plates to determine the contribution of the plastic matrix to rigidity and strength of the encapsulated metal panel design.

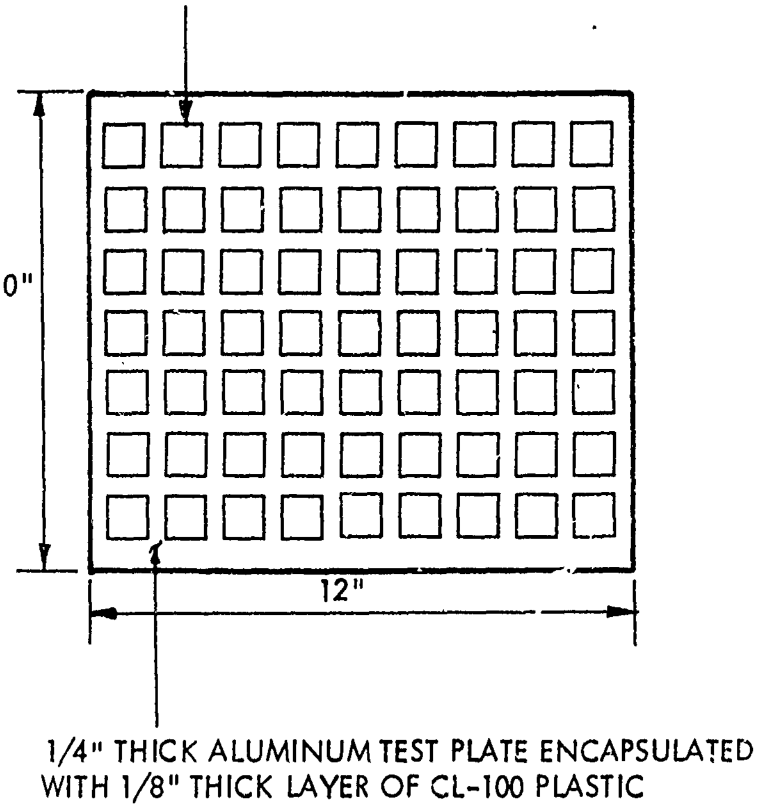
The aluminum plate was sandblasted, cleaned with MEK and encapsulated with a layer approximately 1/8 inch thick of CL-100 crosslinked polyethylene by rotational molding. Bending tests of samples were conducted on a Tinius Olsen machine. The test data, as abstracted from graphic stress-strain curves, indicated that the addition of the plastic material increased the yield strength of the metal-plastic combination in the order of 12,000 psi. Figure 35 shows a tabulation of test sample geometric data and test conditions.

In order to determine an optimum container panel design, several experimental panel configurations were designed and built. The metal diaphragms (sidewall panels) needed to have enough structural strength in combination with adequate allowance for through-flow of the plastic powder during the molding operation. Particular interest was focused on size and shape of perforations in the metal and how the plastic would flow through openings. Figure 36 shows four experimental panels that were selected for the above described evaluation. Appendix D shows all design details of the panels and how they were attached to the substructure. Sections 3.3.4 and 3.3.5 describe the test results obtained from molding the aluminum subscale container and the resulting engineering analyses.

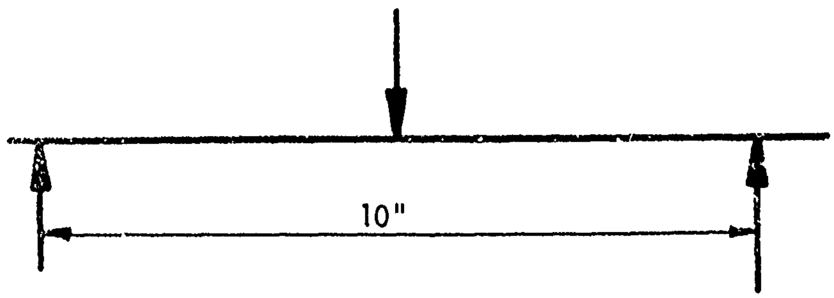
3.3.3 Redesign of Subscale Mold

In order to rotomold plastic around an aluminum container frame, an all aluminum mold was required to avoid differential expansion at elevated temperatures. A mold was designed consisting of six separate panels. The edges of these panels were bolted together around the structure of the container frame, allowing for a gap between the container wall and the mold to obtain the desired thickness of plastic encapsulation. One of the panels featured a small door through which the mold could be charged with plastic powder. The inside surfaces of the mold panels were sculptured to suit the outside surfaces of the container.

TEST PLATE GEOMETRY



TEST CONDITION



TEST RESULT

P_{yield} ÷ 950 LBS. WITHOUT PLASTIC ENCAPSULATION

÷ 1150 LBS. WITH PLASTIC ENCAPSULATION

FIGURE 35

ENCAPSULATED TEST PLATE BENDING TEST

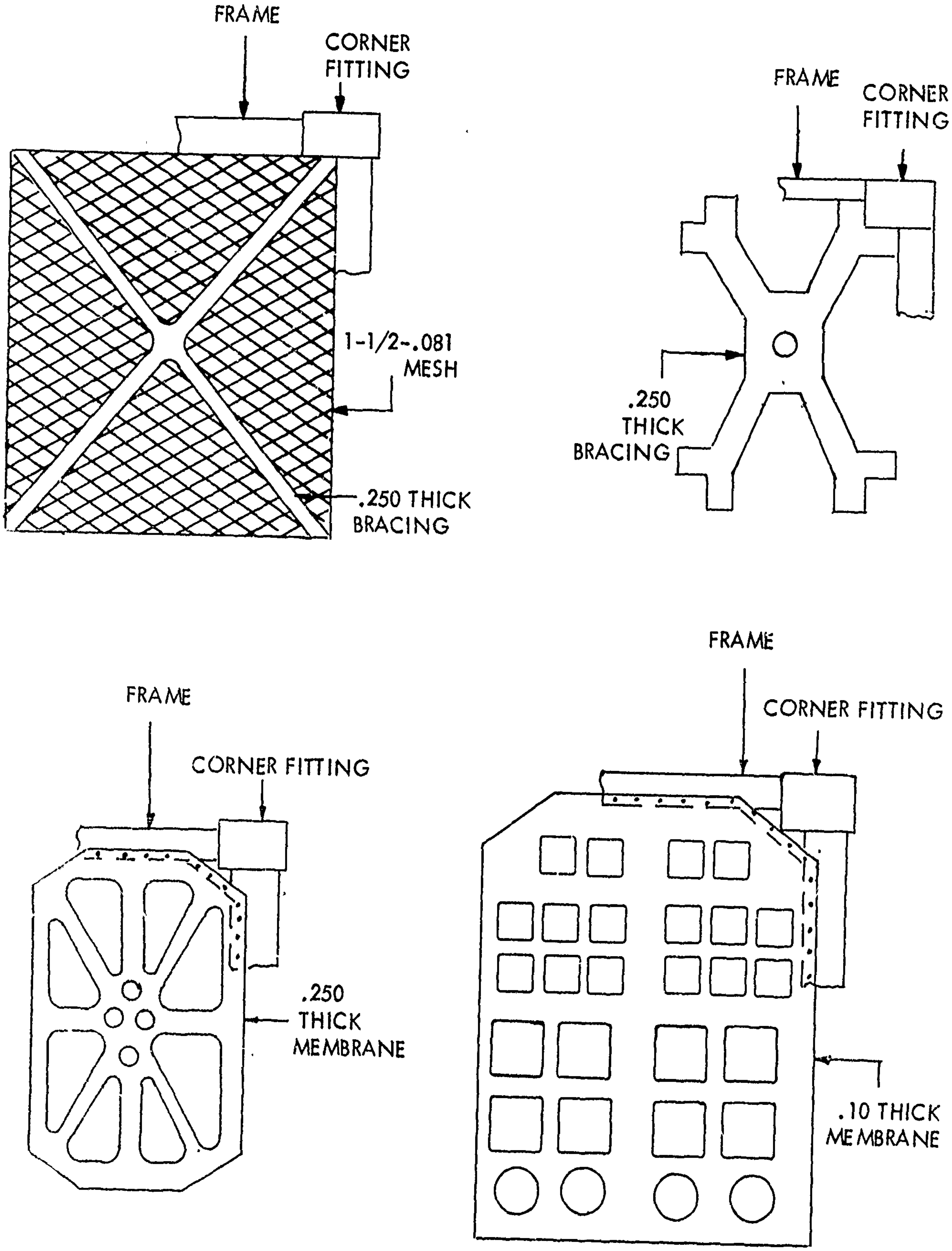


FIGURE 36

ALUMINUM SUBSCALE CONTAINER - TEST PANEL CONFIGURATIONS

To support and restrain the aluminum mold during the rotomolding cycle, a framework of steel tubing was designed and built. See Figures 37 and 38 for an exploded view and an assembled view of the subscale mold plus its substructure.

The steel frame also provided the means of attachment of the fully assembled mold to the rotomolding machine. The aluminum mold was held in place inside the steel frame by leaf spring type deflecting fittings. These fittings were to accommodate the differential expansion between the aluminum mold and the steel frame during the heat cycle.

The steel frame was designed to support the mold up to internal pressures of 5 psi and resist mold deformation caused by such pressures.

Drawings specified a large number of lightening holes in the steel frame and for some recessed areas on outer surfaces of mold plates as an optional weight reduction measure for the mold. These options were not used because an adequate rotomolding machine capacity was established to handle the full load.

Design details for the aluminum subscale container mold, are shown in the engineering drawings in Appendix D.

.3.1 Molding of Additioral Subscale Containers

Upon completion of the redesign of the subscale framework and mold in aluminum, the molding of a subscale TRICON container without the metal reinforcement in the aluminum subscale mold, and the molding of a subscale container with an aluminum framework in the aluminum mold were undertaken.

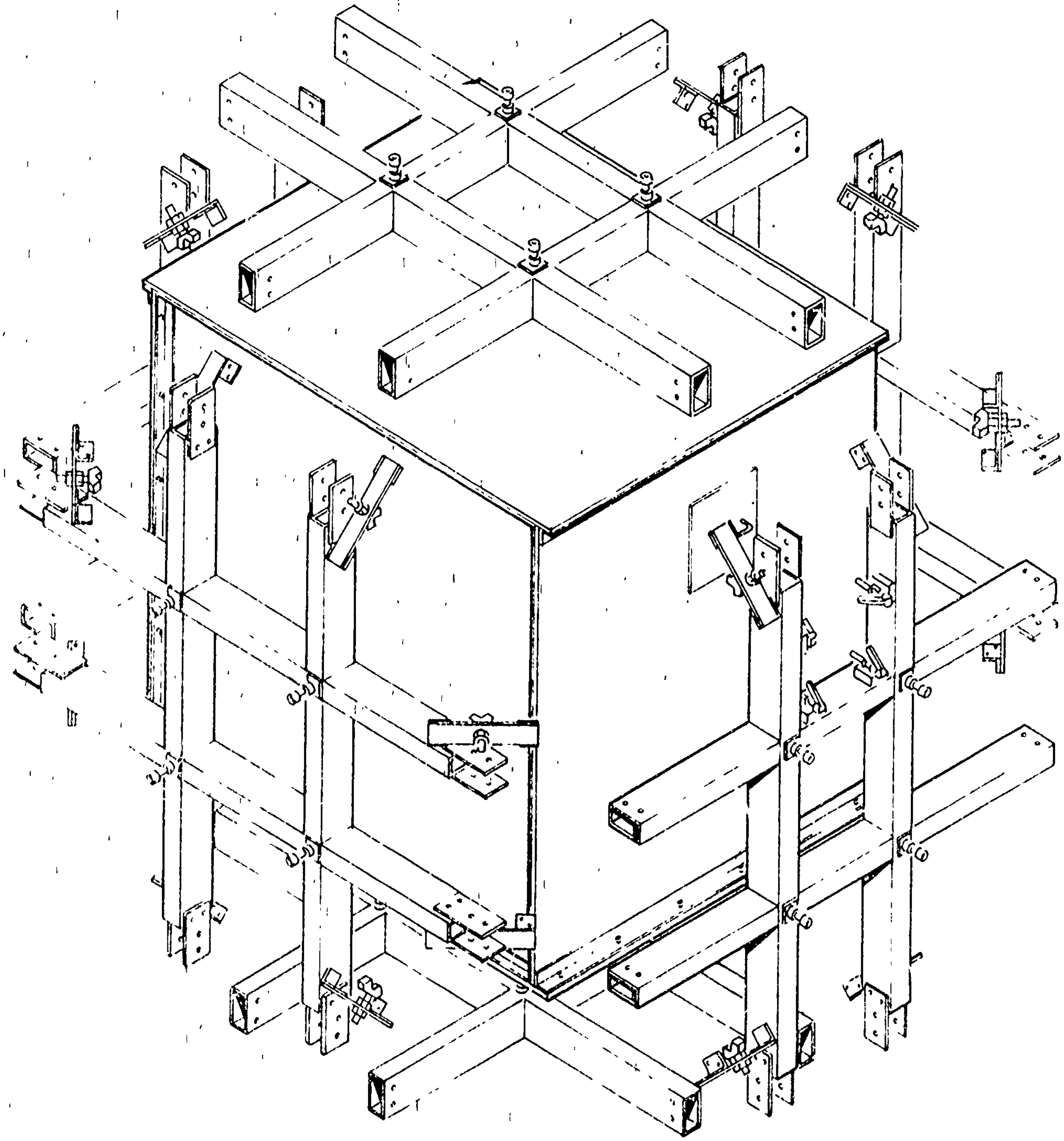


FIGURE 37

ALUMINUM SUBSCALE MOLD - EXPLODED VIEW

LEAF SPRING DEFLECTION
FITTING (TYP)

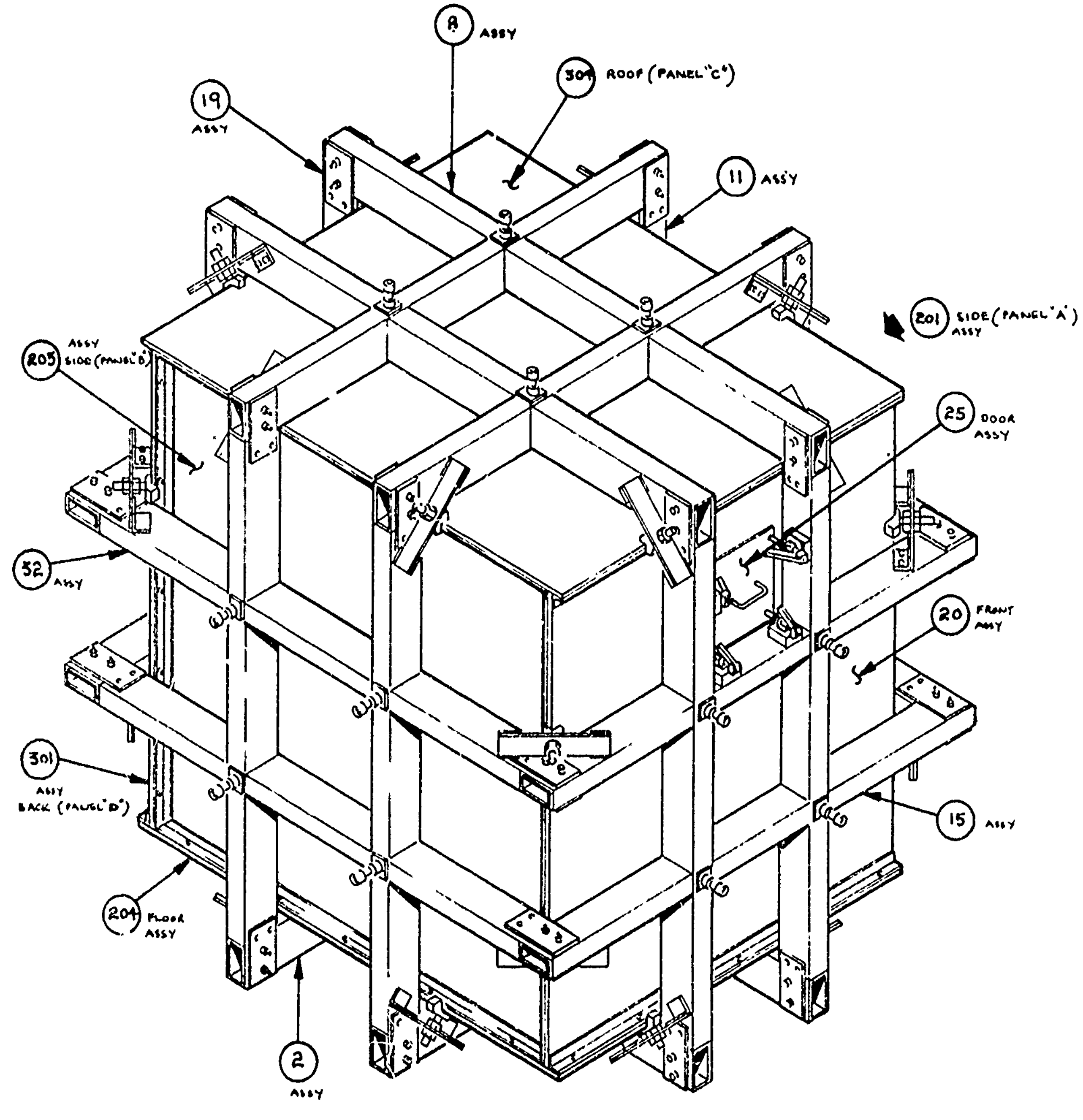


FIGURE 38

ALUMINUM SUBSCALE MOLD - ASSEMBLY

The processing information generated to date was thoroughly reviewed, and the following molding cycle was used to mold a crosslinked polyethylene shell without the aluminum framework:

- o Heatup - 45 minutes
- o Molding at 450°F - 50 minutes
- o Water Quench - 30 minutes
- o Rotation - 10 rpm on major axis
  20 rpm on minor axis

The molded part was closely inspected after it had cooled down and had been removed from the mold. The following observations were made:

- o The surface finish was an accurate mirror image of the mold, having neither pinholes or other defects.
- o The wall thickness was a uniform .50 inch ± .050 inch.
- o Shrinkage was measured to be 0.034 inch per inch, which was approximately 10% higher than the .25 inch thick specimens molded in the materials study. This was considered reasonable in view of the .50 inch wall thickness of the shell.

Further, it was noted after 24, 48, and 96 hours that stress cracks did not develop.

The subscale container with the aluminum framework was molded using the cycle described above, using four hundred pounds of olive drab crosslinked polyethylene as the plastic charge.

An inspection of the molded container yielded the following information:

- o The sidewall panel design shown in Figure 39 was best from the standpoint of thorough encapsulation. Further, the crosslinked polyethylene encapsulating this panel did not develop stress cracks upon aging.

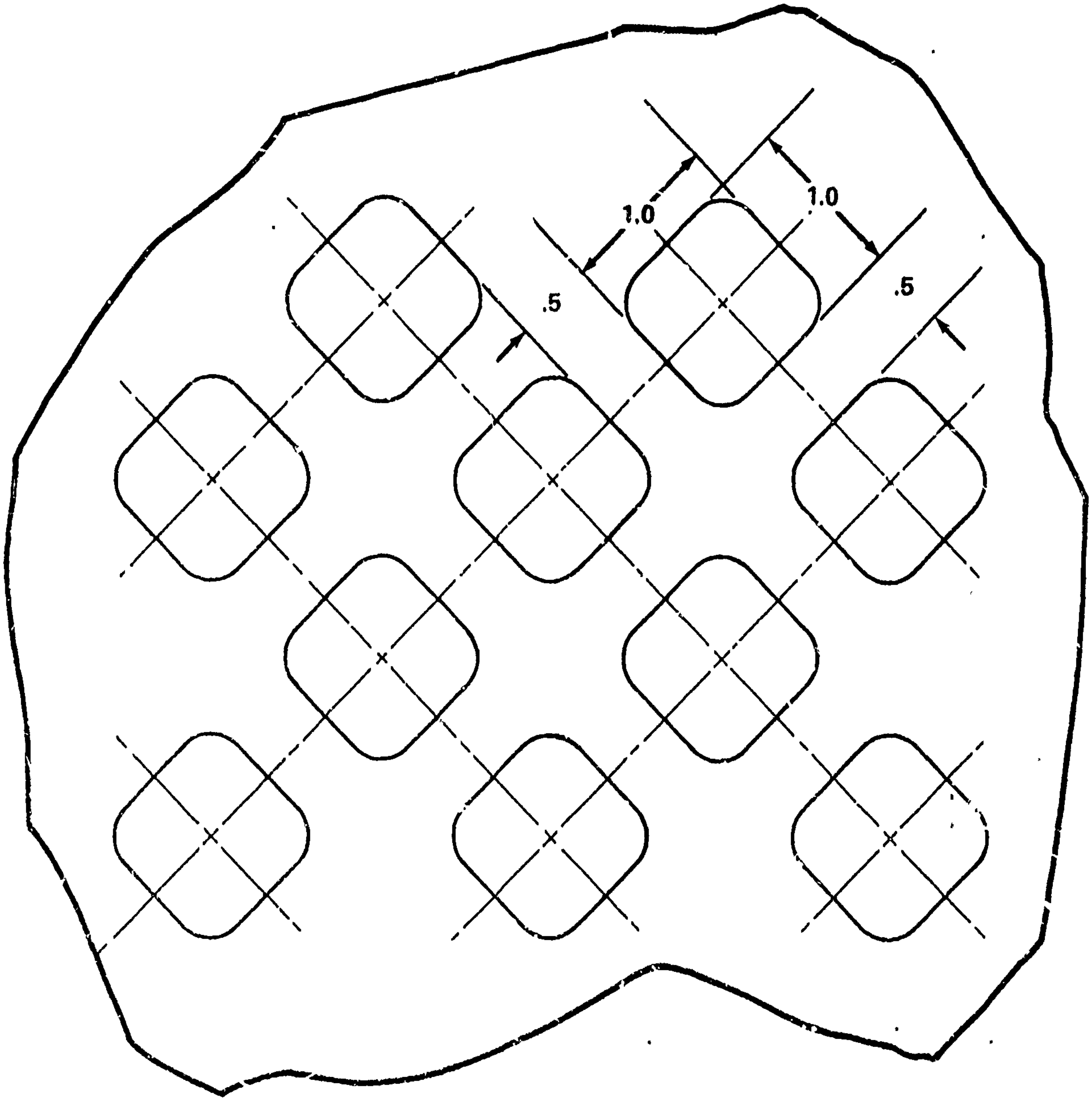


FIGURE 39

–SIDEWALL PANEL DESIGN EXHIBITING BEST ENCAPSULATION BY CROSSLINKED POLYETHYLENE DURING ROTOMOLDING

- None of the other sidewall panels were completely encapsulated. In addition, stress cracks developed in these panels within a matter of hours.
- Complete encapsulation of the corner posts was not achieved.

3.3.5 Engineering Analysis

At this point, a thorough review of all data generated during the program was conducted. The following observations and conclusions were made:

1. By redesigning the subscale container and mold in aluminum, the time required to bring the molding assembly from ambient temperature to molding temperature was reduced from 50 minutes to 45 minutes, and the molding time from 70 minutes to 50 minutes. It was therefore apparent that the effects of thermal degradation of the plastic would be less significant if a full size aluminum framework and mold were used.
2. The sidewall panel shown in Figure 39 was best from the standpoint of complete encapsulation. Further, it was the only sidewall panel configuration that did not subsequently develop cracks.
3. The width of the corner post was too great to allow the plastic material to flow around and encapsulate the metal structure.

It was decided to design the full size TRICON container framework in aluminum, using the sidewall panel configuration shown in Figure 39. The width of the corner posts would be reduced as much as the strength requirements of the container would allow. The full size rotational mold would be designed in the same aluminum alloy as the container framework to insure compatibility in thermal expansion. The mold wall thickness and overall mass of the mold would be minimized as much as possible to provide for maximum heatup and cool down rates.

It was further decided to conduct the process optimization study concurrent with the design of the full size container and mold. Since the structural member design was governed by the design objectives established early in the program, it was felt that running the two efforts concurrently would save time and be within good

engineering practices. An additional benefit of conducting the two efforts simultaneously was that pertinent data generated during the process optimization study could be incorporated into the design effort; for example, the best method of preparing the aluminum framework surface to achieve a good plastic-aluminum bond.

3.4 FULL SIZE CONTAINER AND MOLD DESIGN

3.4.1 Full Size Container Design

The design of the full size container was undertaken with the following objectives:

- To meet the TRICON design load requirements
- To utilize rotational molding technology
- To minimize container weight
- To minimize the manufacturing cost

The finalized design consisted of a structural framework and sidewall panels constructed of Al 2219 aluminum completely encapsulated with olive drab crosslinked polyethylene. The three outer faces of each of the eight corner fittings were not coated, since they served as the framework-mold index points. The redesign produced a weight reduction from 2818 to 1906 pounds. Figure 40 is a detailed weight comparison between the full size TRICON with a steel framework and the full size TRICON with an aluminum framework. The Engineering drawings and design calculations are provided in Appendix E, drawing # R-677059P08, Sheets 1 through 5.

The main components of the container were:

- Frame Assembly - a welded structure consisting of eight corner fittings, vertical and horizontal tie members between the corner fittings and the floor structure.

- Panel Assemblies (three sides and roof) - plates, perforated with rectangular cutouts except along the edges. The edges are riveted to the

	STEEL FRAME	ALUMINUM FRAME (STEEL CORNER FITTINGS)	ALL ALUMINUM FRAME
WEIGHT OF PLASTIC	400	400	400
TOP (SIDES, BACK, ROOF)	800	375	365
(CORNER POSTS)	195	70	70
(UPPER RAILS)	68	24	24
CORNER FITTINGS	176	176	64
BASE FRAME, CROSS MEMBERS AND FORKLIFT POCKETS	510	192	182
OTHER COMPONENTS			
DOORS	200	200	200
OAK FLOOR	340	340	340
HINGES	44	44	44
LOCKS	60	60	60
PIPES	25	25	25
TOTAL	2,818	1,906	1,774

FIGURE 40

WEIGHT COMPARISON - PLASTIC TRICON WITH ALUMINUM VS. STEEL FRAMEWORK

frame corner posts and frame rails. Each panel has a number of stiffener angles from edge to edge.

- o Door Assemblies - Left hand and right hand doors, designed with channel type frame and perforated plate field.

  NOTE: Alternate design calls for the use of standard commercially available doors with wood core and metal sheeting for the prototype containers only. This approach eliminates the need for fabrication of separate door molds (see Appendix F, Drawing #E2MOLDR677079PO8), reducing the initial total container mold cost by approximately 15%.

3.4.2 Full Size Mold Design

In the design of the mold for the full size container, a design concept was used similar to that of the aluminum subscale mold. The latter had proved to be working with very little difficulty and some elements such as the corner spring fittings could be transferred from the subscale mold without change.

Due to the larger size of the mold and heavier weights, the aluminum mold plate gage and the number of steel frame members around the mold had to be increased. A completely new set of attachment brackets had to be included in the design to utilize Boeing's new large rotomold machine.

A need for up to 5 psi pressure (above the atmospheric pressure) was expected inside the mold and the steel frame around the mold was to support the mold panels to prevent buckling due to such pressure. The need to increase pressure inside the mold was dictated by observations that during the cooling period some shrinkage took place and the plastic had the tendency to move away from the mold wall. Increased internal mold pressure would prevent such buckling inwards.

Mold side wall panels were designed to be fabricated from one inch thick plates which required sculpturing on the inner surfaces to accommodate corner fittings and various other cutouts.

An access door was designed into one of the mold panels with handles and clamps for easy handling. The access door permitted a plastic charge to be placed in the mold after the framework had been indexed to the mold. Engineering drawings of the full size mold are provided in Appendix F.

3.5 PROCESS OPTIMIZATION STUDY

The objective of the process optimization study was to further delineate the process parameters and eliminate the stress cracking problem. To this end, studies on flow characteristics, molding temperature, encapsulation, sidewall panel configuration and adhesion were conducted and completed.

3.5.1 Flow Characteristics

A study of flow characteristics of five different materials was conducted. The materials were crosslinked polyethylene, a crosslinked polyethylene having a 2% chopped fiberglass blend, linear polyethylene, a linear polyethylene having a 2% chopped fiberglass blend, and Hytrel 5525 (a polyester-urethane blend). The study was conducted by molding the above materials at different temperatures in a 12 by 12 by 12 inch aluminum mold and inspecting the molded part for uniformity of wall thickness and smoothness of inside surface. The results of this study are shown in Figure 41.

The part molded with crosslinked polyethylene was superior from the standpoint of uniformity of thickness and surface quality of the inside wall. The parts molded with linear polyethylene were irregular on the inside surface, which caused the wall thickness to vary considerably.

MATERIAL	MOLDING TEMP. 450°F		MOLDING TEMP. 500°F	
	Wall Uniformity	Inside Part Finish	Wall Uniformity	Inside Part Finish
Crosslinked Polyethylene (CL-100)	Good	Good	Satisfactory	Good
Crosslinked Polyethylene and 2% Fiberglass	Fair	Fair	Fair	Fair
Linear Polyethylene (PEP 770)	Fair	Good	Poor	Poor (bubbles & irregular surface)
Linear Polyethylene and 2% Fiberglass	Poor	Poor	Poor	Poor
Hytrel 5520 (Polyester urethane blend)	Poor	Poor	Fair	Poor

FIGURE 41

FLOW CHARACTERISTICS OF FINAL CANDIDATE MATERIALS DURING ROTOMOLDING

Although several attempts were made to mold parts with the Hytrel 5520, we were unsuccessful in making a good part. Maximum moldable part thickness appeared to be approximately 1/8 inch. Attempts to mold thicker wall sections resulted in parts with unfused material on the inside surface.

3.5.2 Encapsulation

The encapsulation studies were conducted to establish parameters for encapsulation of the metal sidewalls. The tests were designed to provide comparative data on effects of opening sizes and web thicknesses in the metal inserts on encapsulation and the relationship of standoff distance to encapsulability. The tests were conducted using an aluminum mold having 12 by 12 by 12 inch dimensions (see Figure 42). Metal inserts having different hole patterns were positioned inside the mold with a uniform spacing between the metal insert and the mold wall (see Figure 43).

A. Heatup and Cool Down Studies

The initial step in the encapsulation studies was to develop heatup and cool down rate information. This work was accomplished on the McNeil-Akron rotocast equipment located in the Manufacturing Research and Development Laboratory at the Boeing Auburn, Washington, Central Fabrication and Services facility. Thermocouples were attached to the outside of the mold and to the center of the aluminum insert located at the bottom of the mold. The oven on the rotocast equipment was set at 500°F. The mold was rotated inside the oven during heatup. After eight (8) minutes at 500°F, the mold was removed from the oven and rotated in the cold water spray cooling chamber. The data shown in Figure 44 was generated in this manner.

Using the heatup and cool down data thus developed, the encapsulation of 1/4 inch thick aluminum inserts with crosslinked polyethylene was undertaken. The inserts had various sized openings and web widths (see Figure 45). Tests were conducted with the mold being charged at room

FIGURE 42

ALUMINUM MOLD USED IN ENCAPSULATION STUDIES

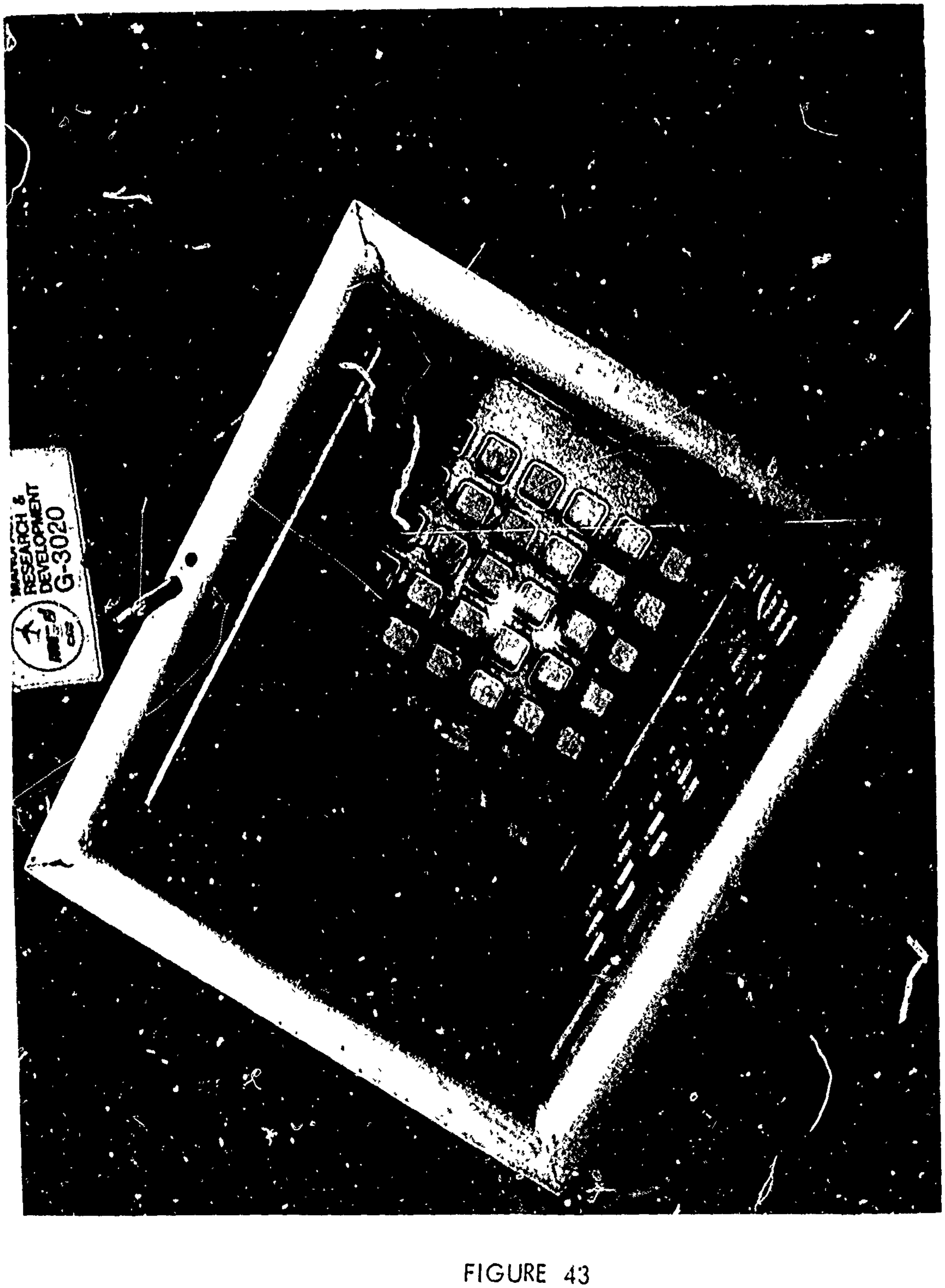


FIGURE 43

POSITIONING OF ALUMINUM INSERTS INSIDE MOLD

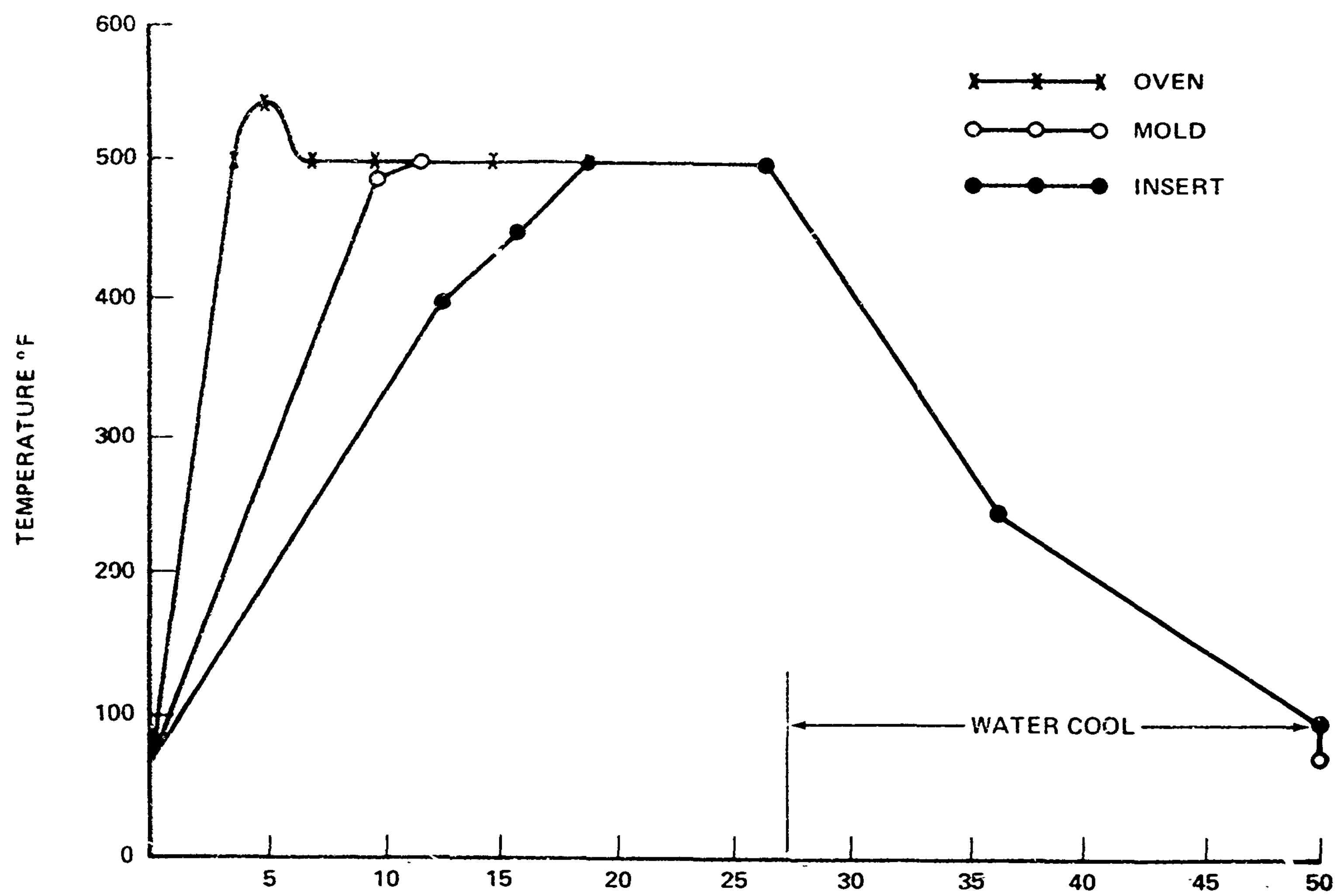


FIGURE 44
HEATUP AND COOLDOWN STUDY RESULTS

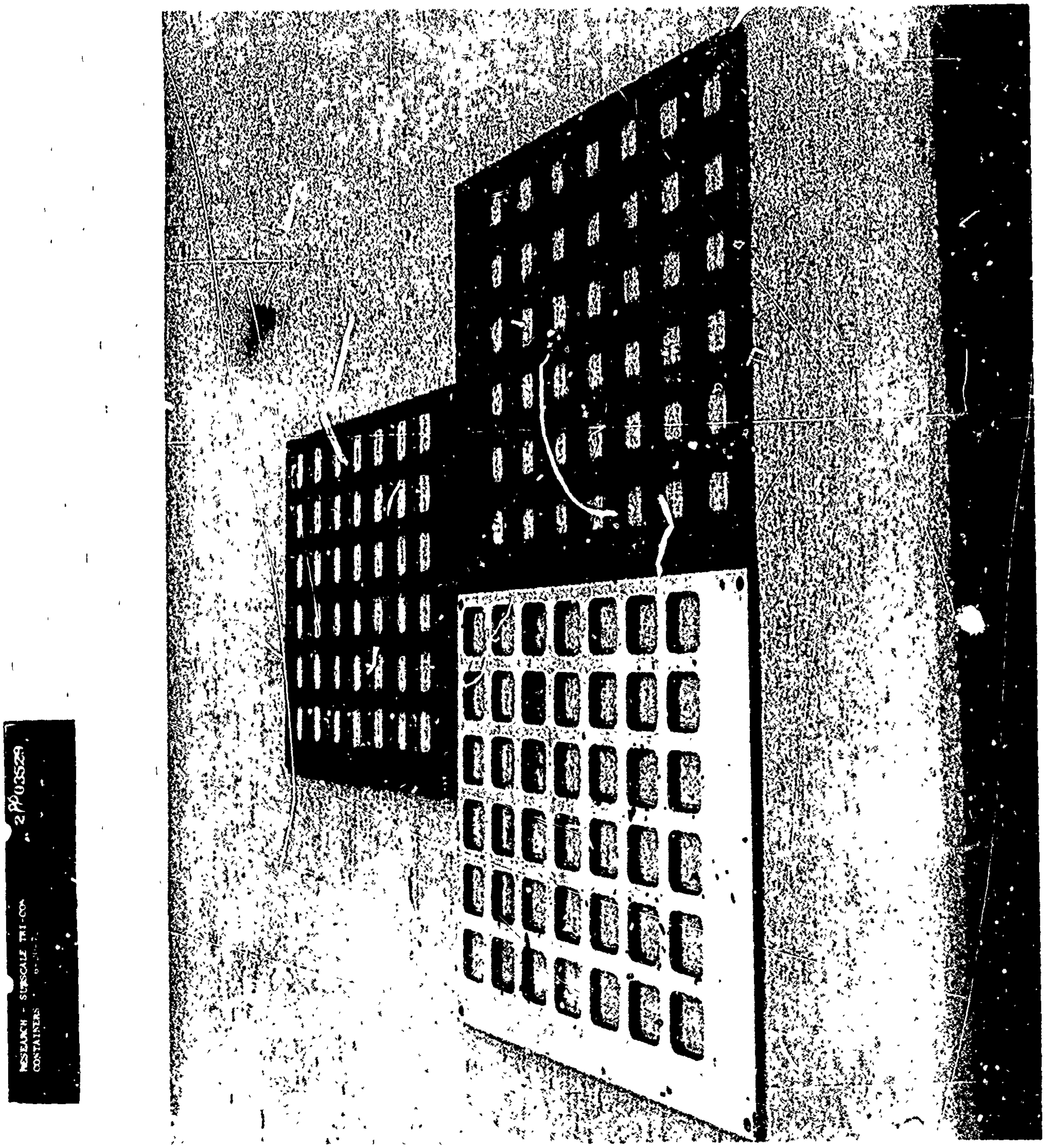


FIGURE 45

TYPICAL METAL INSERTS USED IN ENCAPSULATION STUDIES

temperature, and with the mold being preheated before charging. The results of these tests are shown in Figure 46.

From the encapsulation studies conducted with CL-100 crosslinkable polyethylene, two important pieces of information were obtained:

- o Best encapsulation was achieved by charging the mold at room temperature and molding for 8 minutes after reaching 400°F–450°F.
- o An opening-web ratio of 2:1 or greater is necessary for good encapsulation regardless of standoff distance between the insert and the mold. As indicated by the data shown in Figure 44, good encapsulation was achieved with the opening-web sizes of 1.0 - .5 inch, 1.1 - .4 inch, and 1.2 - .3 inch, or ratios of 2:1, 2.75:1, and 4:1, respectively. Poor encapsulation was experienced with opening-web sizes of .75 - .5 inch and 1.5 - 1.0 inch, or a 1.5:1 ratio.

Identical encapsulation tests were conducted with high density polyethylene (PEP #770), Union Carbide. In general, the high density polyethylene produced an irregular interior surface on the molded part (Figure 47). Several of the molded parts contained voids between the plastic and the metal insert. The results of these tests are shown in Figure 48.

Encapsulation tests were conducted with crosslinked polyethylene and steel inserts, and using high density polyethylene and steel inserts. The overall results were poor with both plastic materials. Although the results obtained with the crosslinked polyethylene were superior to those obtained with high density polyethylene, the quality was not adequate for use on the full size TRICON. The results of these tests are shown in Figures 49 and 50.

ALUMINUM, 1/4' THICK	Mold charged at RT–Molded 8 minutes after reaching:			Mold preheated to Temp. below, Molded for 12 minutes with oven set at 500°F		
	400°F	450°F	500°F	350°F	400°F	450°F
Insert 1/8" inside mold wall						
.75" opening, .5" web	Poor	N.T.	Fair*	N.T.	N.T.	Poor
1.0" opening, .5" web	Fair*	Good	Fair*	Poor		Poor
1.1" opening, .4" web	Good	N.T.	Good	Poor	Poor	N.T.
1.5" opening, 1.0" web	N.T.	Poor	N.T.	N.T.	N.T.	Poor
1.2" opening, .3" web	Good	Good	N.T.	Poor	Poor	
Insert 3/16" inside mold wall						
.75" opening, .5" web	Poor	Poor*	N.T.	N.T.	N.T.	N.T.
1.0" opening, .5" web	Good	[illegible]r-Good	Fair*	Poor	Poor	N.T.
1.1" opening, .4" web	N.T.	Good	Good	Poor	Poor	N.T.
1.5" opening, 1.0" web	Poor	N.T.	N.T.	N.T.	N.T.	N.T.
1.2" opening, .3" web	Good	Good	Good		Poor	

* Hollow spots between web and plastic

N.T. = Not Tested

FIGURE 46

ENCAPSULATION OF ALUMINUM INSERTS WITH CL-100 CROSS-LINKED POLYETHYLENE (OLIVE DRAB)

ALUMINUM, 1/4" THICK	Mold charged at RT-Molded 8 minutes after reaching:			Mold preheated to Temp. below, Molded for 12 minutes with oven set at 500°F		
	400°F	450°F	500°F	350°F	400°F	450°F
Insert standoff, 1/8"						
3/16" thick, 1.0" opening, .5" web	Poor	Poor	Poor	N.T.	Poor	Poor
3/16" thick, 1.1" opening, .4" web	N.T.	N.T.	N.T.	N.T.	N.T.	Poor
3/16" thick, 1.15" opening, .35" web	Poor	Poor	Poor	N.T.	Poor	Poor
1/4" thick, 1.0" opening, .5" web	Poor	Poor	N.T.	N.T.	N.T.	N.T.
3/16" thick, 1.5" opening, 1" web	N.T.	N.T.	Poor	N.T.	N.T.	N.T.
Insert Standoff, 3/16"						
3/16" thick, 1.0" opening, .5" web	Poor	Poor	Fair	Poor	Poor	Poor
3/16" thick, 1.2" opening, .3" web	Poor	Poor	N.T.	Poor	Poor	Poor
3/16" thick, 1.15" opening, .35" web	Fair	Fair	Fair	Poor	Poor	Poor
1.4" thick, 1.0" opening, .5" web	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
3/16" thick, 1.5" opening, 1.0" web	N.T.	N.T.	Good	N.T.	N.T.	N.T.

FIGURE 47

ENCAPSULATION OF ALUMINUM INSERTS WITH HIGH DENSITY POLYETHYLENE

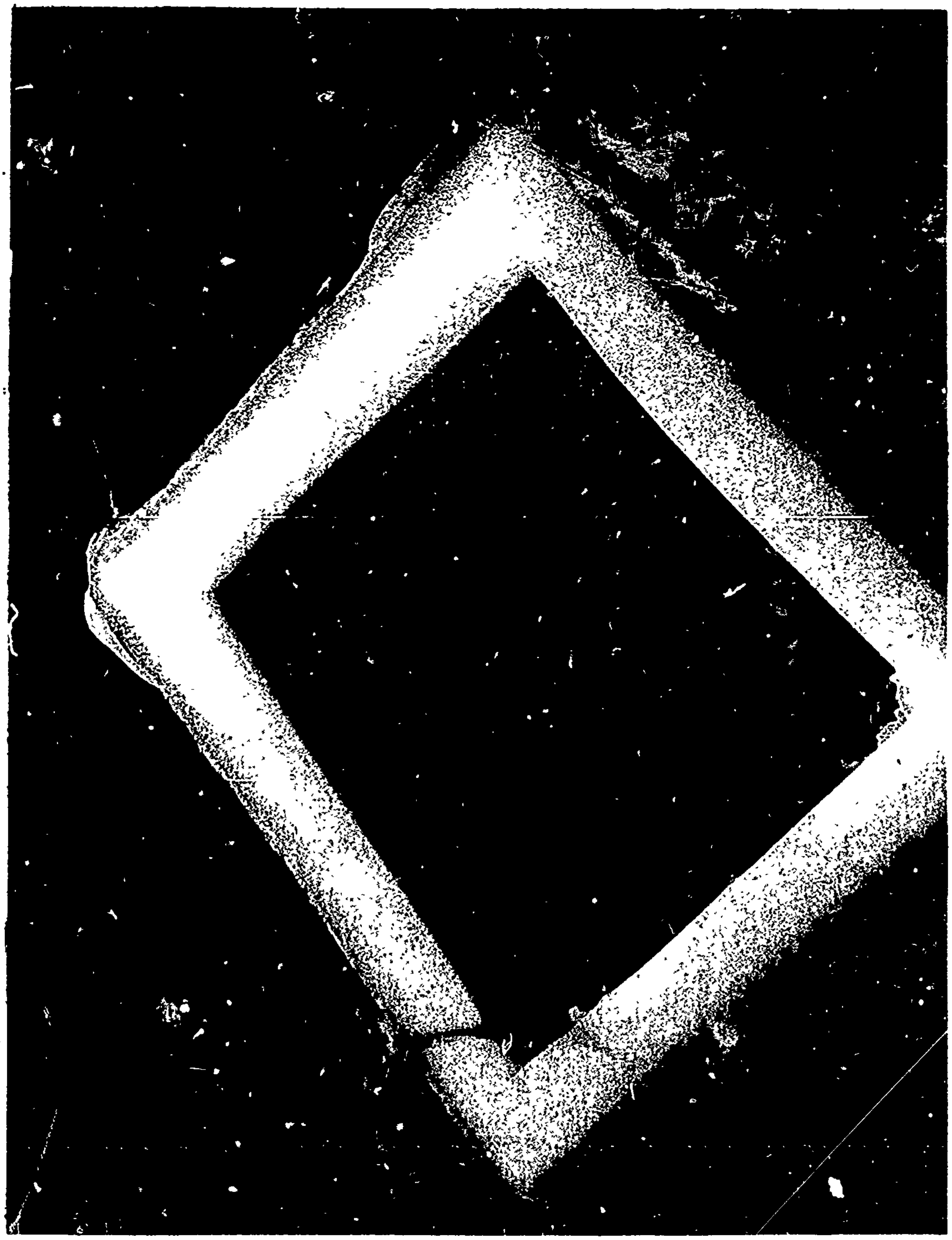


FIGURE 48

TYPICAL RESULT OF ENCAPSULATION TESTS
USING HIGH DENSITY POLYETHYLENE AND ALUMINUM INSERTS

STEEL, 1/4" THICK	Mold charged at RT-Molded 8 minutes after reaching:		
	400°F	450°F	500°F
Insert 1/8" inside mold wall			N.T.
.75" opening, .5" web	Poor	Poor	
1.0" opening, .5" web	Poor - Fair	Poor	
1.1" opening, .4" web	N.T.	N.T.	
1.5" opening, 1.0" web	N.T.	N.T.	
1.2" opening, .3" web	Poor	Fair	N.T.
Insert 3/16" inside mold wall			
.75" opening, .5" web	N.T.	Poor*	N.T.
1.0" opening, .5" web		Good*	
1.1" opening, .4" web		N.T.	
1.5" opening, 1.0" web	N.T.	Poor*	N.T.
1.2" opening, .3" web			

* Hollow spots between web and plastic

N.T. = Not tested

FIGURE 49

ENCAPSULATION OF STEEL INSERTS WITH
CL-100 CROSSLINKED POLYETHYLENE (OLIVE DRAB)

STEEL, 3/16 AND 1/4"	Mold charged at RT-Molded 8 minutes after reaching:		
	400°F	450°F	500°F
Insert standoff 1/8"			
3/16" thick, 1.0" opening, .5" web	Poor	Poor	N.T.
3/16" thick, 1.15" opening, .35" web	Poor	Poor	N.T.
1/4" thick, 1.0" opening, .5" web	Poor	Poor	N.T.
Insert standoff 3/16"			
3/16" thick, 1.0" opening, .5" web	N.T.	Fair	N.T.
3/16" thick, 1.15" opening, .35" web	N.T.	Poor	N.T.
1/4" thick, 1.0 opening, .5" web	N.T.	Poor	N.T.

N.T. = Not Tested

FIGURE 50

ENCAPSULATION OF STEEL INSERTS WITH HIGH DENSITY POLYETHYLENE (PEP #770)

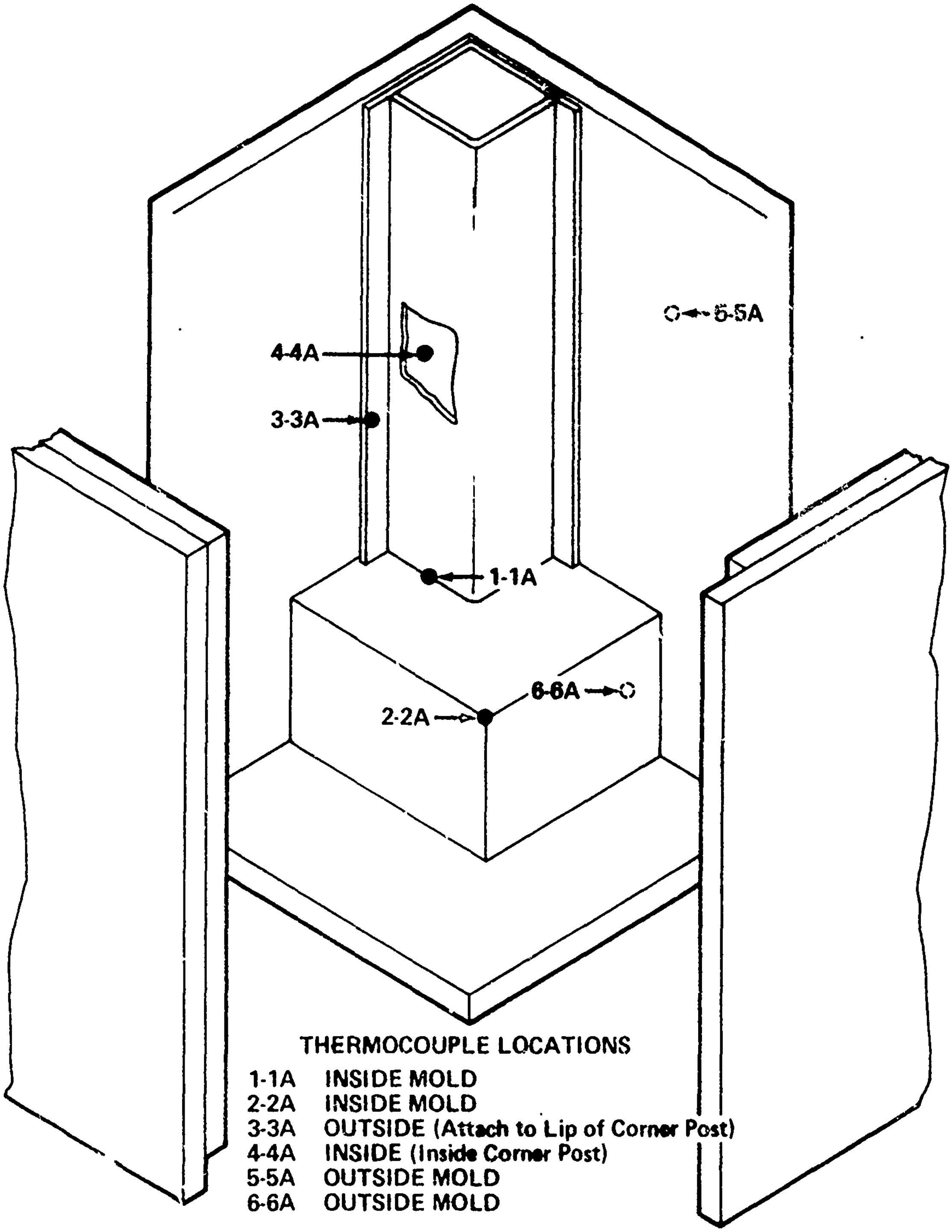
Our experience in rotational molding subscale containers indicated that the mass of the corner fittings and corner posts presented heatup and cool down problems. Tests were therefore conducted to establish heatup and cool down rates of a simulated corner block and section of the corner post. Figure 51 shows the test setup. From these tests it was determined that approximately 70 minutes are required to bring the corner fitting post juncture to a molding temperature of 440°F (see Figure 52).

This data correlated well with the thermocouple study made on the subscale mold and framework, substantiating initial evidence that the cool down time of the full size container could not be expected to be reduced sufficiently to reduce plastic shrinkage. It was now apparent that reduction of the cooling rate as a solution to the stress cracking problem was not possible with the equipment available.

CL-100 crosslinked polyethylene blended with 2% by weight of 1/8 inch chopped fiberglass strands was the first plastic-fiberglass blend used in encapsulation tests with aluminum inserts. The tests, summarized in Figure 53, indicated that it was not possible to completely encapsulate the metal inserts. The addition of the fiberglass strands sufficiently inhibited the plastic flow to prevent good encapsulation. The success achieved with an aluminum insert with a 1.0 inch opening and 0.5 inch web using a 3/16 inch standoff (Figure 54) on the first test could not be consistently duplicated on subsequent tests.

The results of the encapsulation tests on high density polyethylene were so poor that no attempt was made to encapsulate with a blend of high density polyethylene and glass fibers.

Encapsulation tests were conducted using the Hytrel 5520 polyester-polyurethane elastomer and aluminum inserts. A variety of molding cycles was attempted without successfully determining the optimum molding cycle.



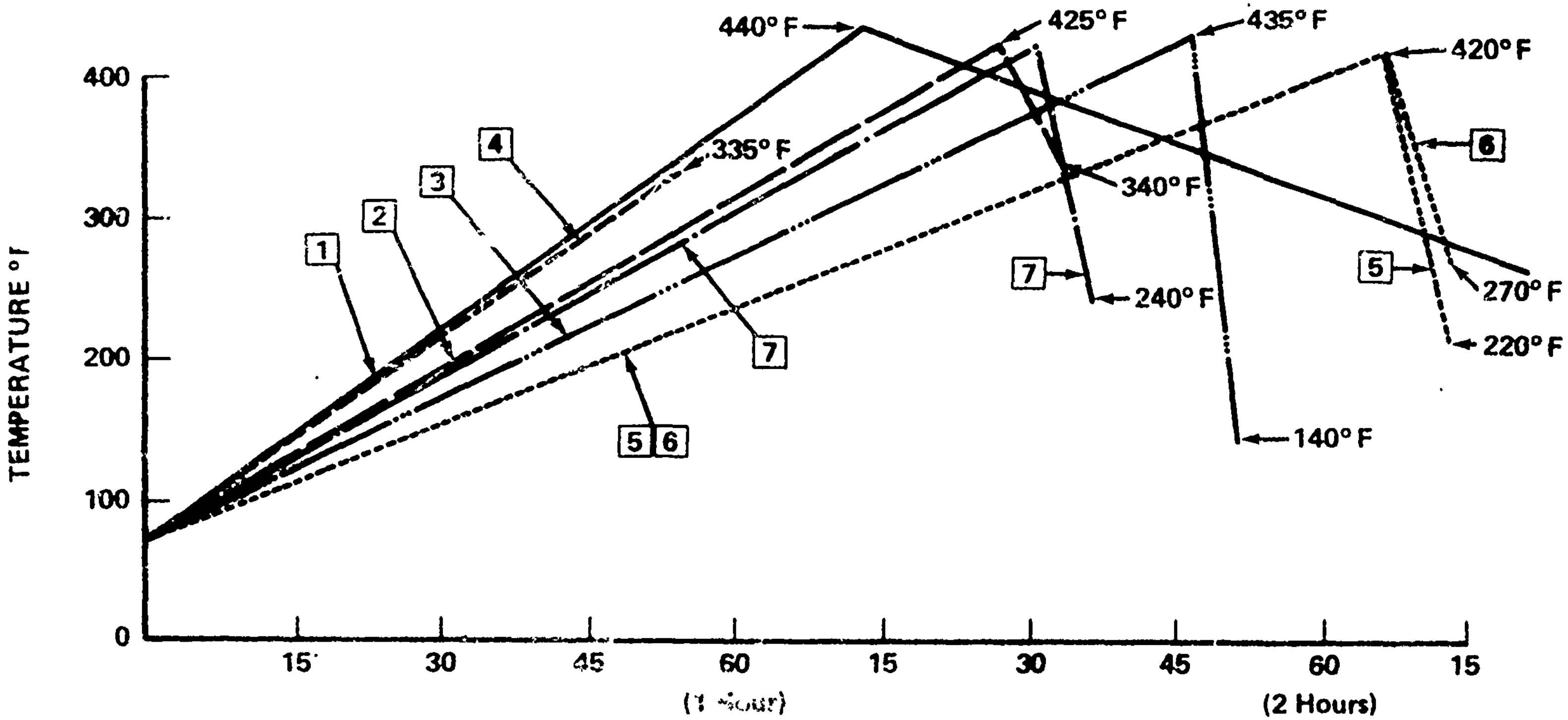
THERMOCOUPLE LOCATIONS

1-1A	INSIDE MOLD
2-2A	INSIDE MOLD
3-3A	OUTSIDE (Attach to Lip of Corner Post)
4-4A	INSIDE (Inside Corner Post)
5-5A	OUTSIDE MOLD
6-6A	OUTSIDE MOLD

FIGURE 51

–TEST SET-UP FOR ESTABLISHING HEATUP AND COOLDOWN RATES OF CORNER FITTING AND POST OF 4′ x 4′ x 3′ CONTAINER

[1] TEST UNIT EMPTY – AIR COOL
[2] TEST UNIT EMPTY – MACH SPRAY QUENCH, 5-MIN
[3] TEST UNIT EMPTY – MACH SPRAY PLUS 1/2" HOSE, 5 MIN QUENCH
[4] TEST UNIT FILLED WITH P/E – TEST NOT COMPLETED MOLD FELL FROM MACHINE
[5] TEST UNIT RE-HEATED WITH MOLDED P/E MACHINE – SPRAY PLUS 1/2" HOSE 5 MIN QUENCH
[6] TEST UNIT RE-HEATED WITH MOLDED P/E MACHINE – SPRAY ONLY – LOWER SPRAY ADDED 5 MIN
[7] TEST UNIT RE-HEATED WITH MOLDED P/E STREAM OF WATER FROM NOZZLES – UPPER AND LOWER



* Temperatures Recorded by Thermocouple 1-1A, Figure 31

FIGURE 52
–HEATUP AND COOLDOWN RATES OF CORNER FITTING AND CORNER POST TEST SETUP*

ALUMINUM, 3/16" THICK	Mold charged at RT–Molded for 8 minutes after reaching:		Mold preheated to temp below and Molded 25 minutes with oven at 500°F	
	400°F	450°F	350°F	400°F
1/8" Standoff				
1.0" opening, 0.5" web	Poor	Poor	Poor	Poor
1.1" opening, 0.4" web	Poor	Poor	Poor	Poor
1.15" opening, 0.35" web	Fair	Fair	Fair	Poor
3/16" Standoff				
1.0" opening, 0.5" web	Poor	Good	Poor	N.T.
1.1" opening, 0.4" web	Poor	Fair	Poor	N.T.
1.15" opening, 0.35" web	Poor	Fair	Poor	N.T.

N.T. = Not Tested

FIGURE 33

ENCAPSULATION OF ALUMINUM INSERTS WITH CROSSLINKED POLYETHYLENE AND 2% FIBERGLASS

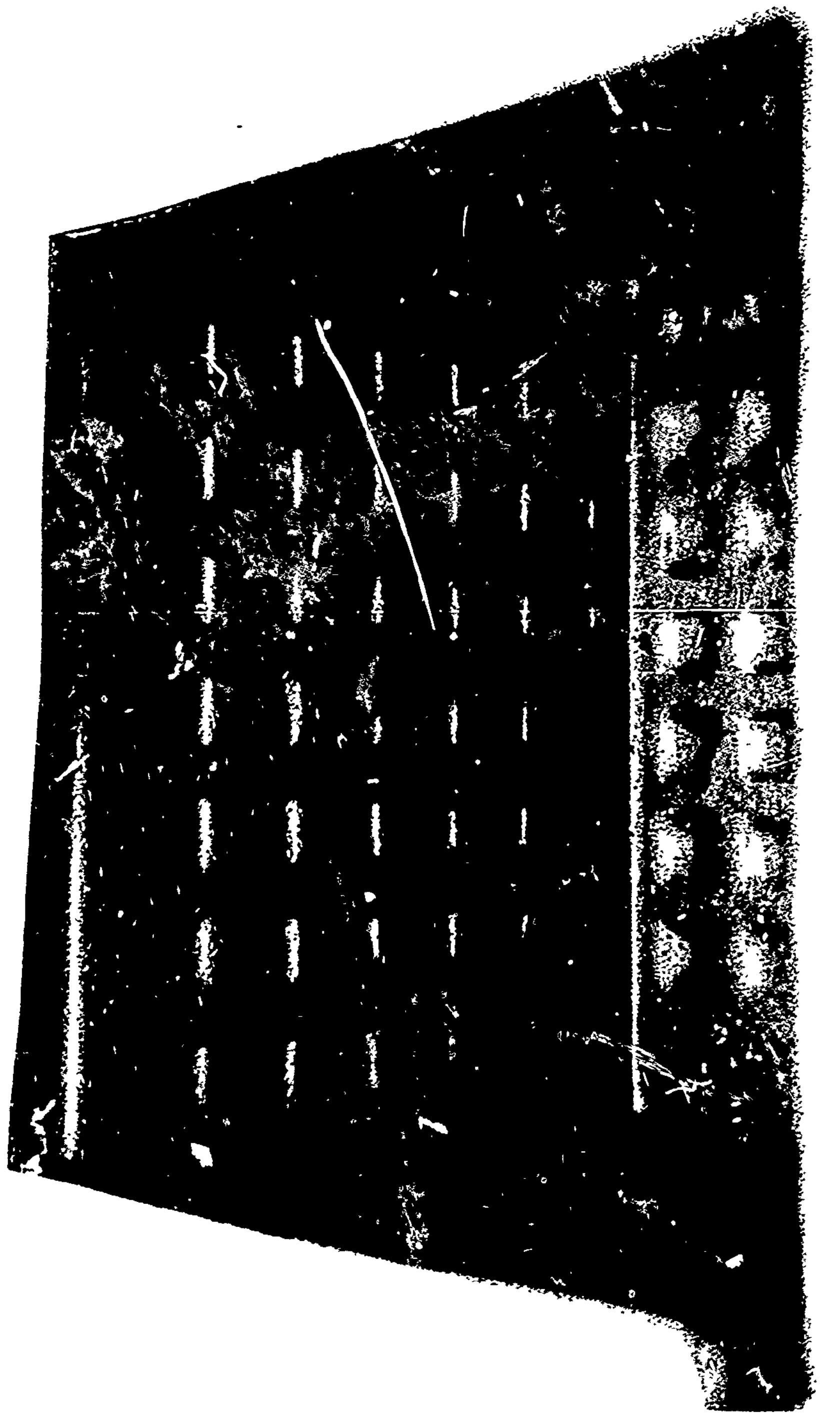


FIGURE 54

ENCAPSULATION OF ALUMINUM INSERT (1" OPENING - 0.5" WEB) WITH CROSSLINKED POLYETHYLENE-FIBERGLASS BLEND

B. Conclusions

The following conclusions were drawn from the encapsulation studies:

1. Crosslinked polyethylene was the best material for encapsulation.
2. With present technology, it is not feasible to encapsulate widths greater than 1-1/2 inch.
3. Charging the mold at room temperature produced best encapsulation of simulated sidewall panels. However, by projecting the time required at elevated temperature for the 4 by 4 by 3 foot subscale container to be molded to the full size TRICON it is apparent that the plastic material will be exposed to 350°F for much longer than 30 minutes. Consequently, a degradation of physical properties can be anticipated.
4. The aluminum inserts encapsulated best. However, the use of an aluminum framework in the full size container dictates the necessity for an aluminum mold. The use of a steel framework and steel mold will reduce the chances of successfully encapsulating the full size TRICON, and incur a high weight penalty.

3.5.3 Adhesion Tests

A series of ddhesion tests was conducted to determine the shear strength of the bond between the metal insert and the encapsulating plastic. Tests were conducted using both aluminum and steel inserts similar to those used in the encapsulation studies. Metal surfaces were prepared three ways:

- o Solvent (MEK) clean only.
- o Sandblast and Solvent (MEK) clean.
- o Sandblast, solvent (MEK) clean, and prime with THIXON AB 1244 metal primer.

Because this was a new developmental material, very little data on molding characteristics was available. The vendor, DuPont, was able to provide some general molding recommendations. However, when tried, it was determined that the recommended cycle was not suitable to our objectives. Schedule and budget did not permit further experimentation with the Hytrel 5520. Figure 55 shows the typical results of attempts to encapsulate aluminum inserts with Hytrel 5520.

It was apparent from the encapsulation tests that the best potential for encapsulating sidewall panels was to use straight CL-100 crosslinkable polyethylene, an insert standoff of either 1/8 or 3/16 inch, charging the mold at room temperature and molding for 8 minutes after reaching 400-450°F, with a 15 minute water cool. To insure capability of duplicating our test results, three, 12 by 12 by 12 inch units were molded using the above parameters. Good encapsulation was achieved in all cases, with the exception of some voids in the area at one end of the aluminum insert where the metal width was approximately 1-1/2 inch. However, after 5 days, one of the units exhibited stress cracking (Figure 56) while the other units did not. The reason for stress cracking occurring in some units while other units molded in an identical manner did not exhibit stress cracking was not determined. Figure 57 shows some of the parts molded during the process optimization studies.

An attempt was made to encapsulate a simulated corner post using the molding cycle described in the preceding paragraph. This attempt was unsuccessful. The plastic material flowed against the mold. However, the mass of metal in the corner post prevented sufficient heatup to cause plastic material to bond to the corner post early enough in the molding cycle. Consequently, all of the plastic coated the mold walls and did not coat the corner posts.

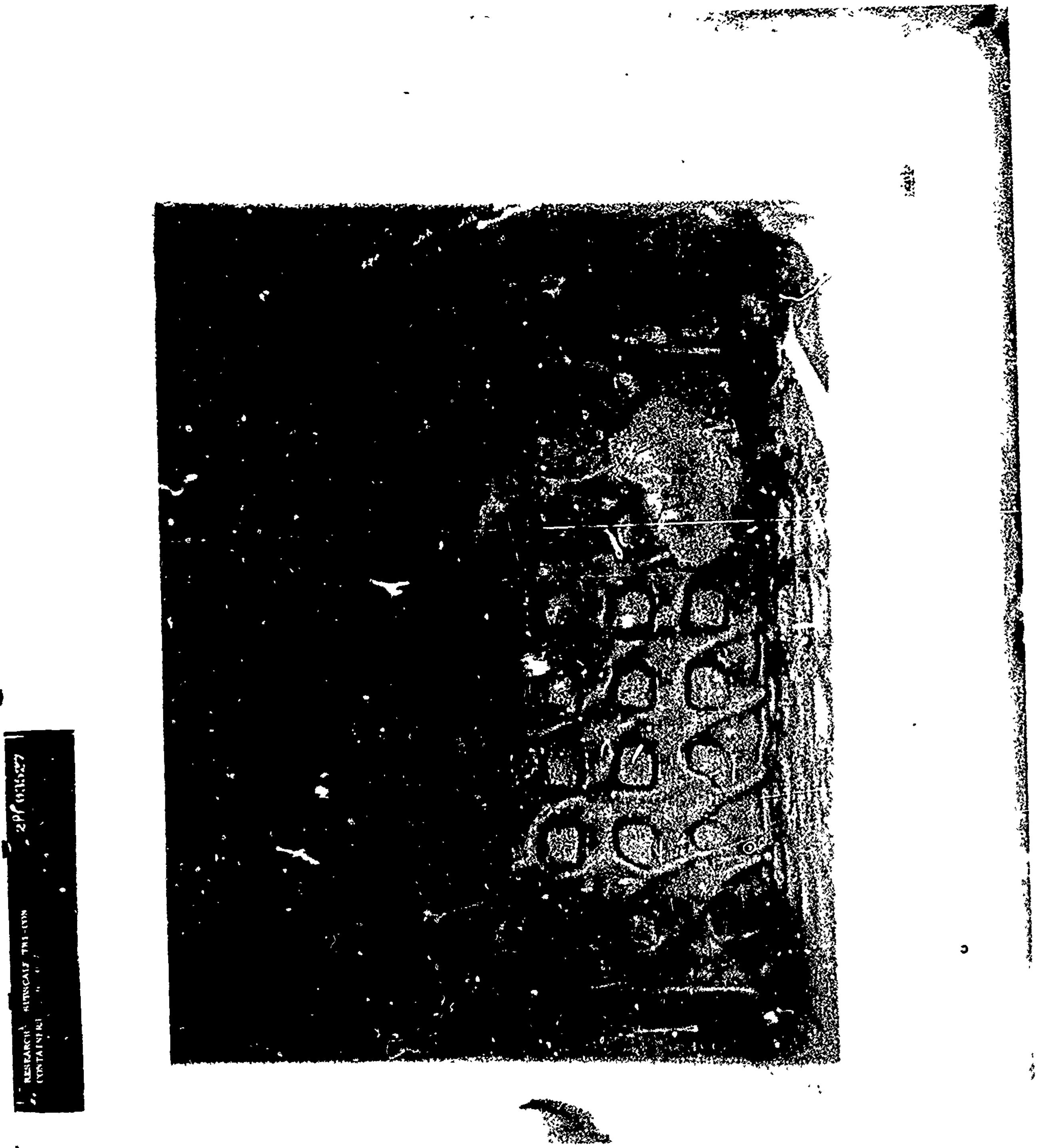


FIGURE 55

TYPICAL RESULT OF ENCAPSULATION TESTS USING HYTREL 5520

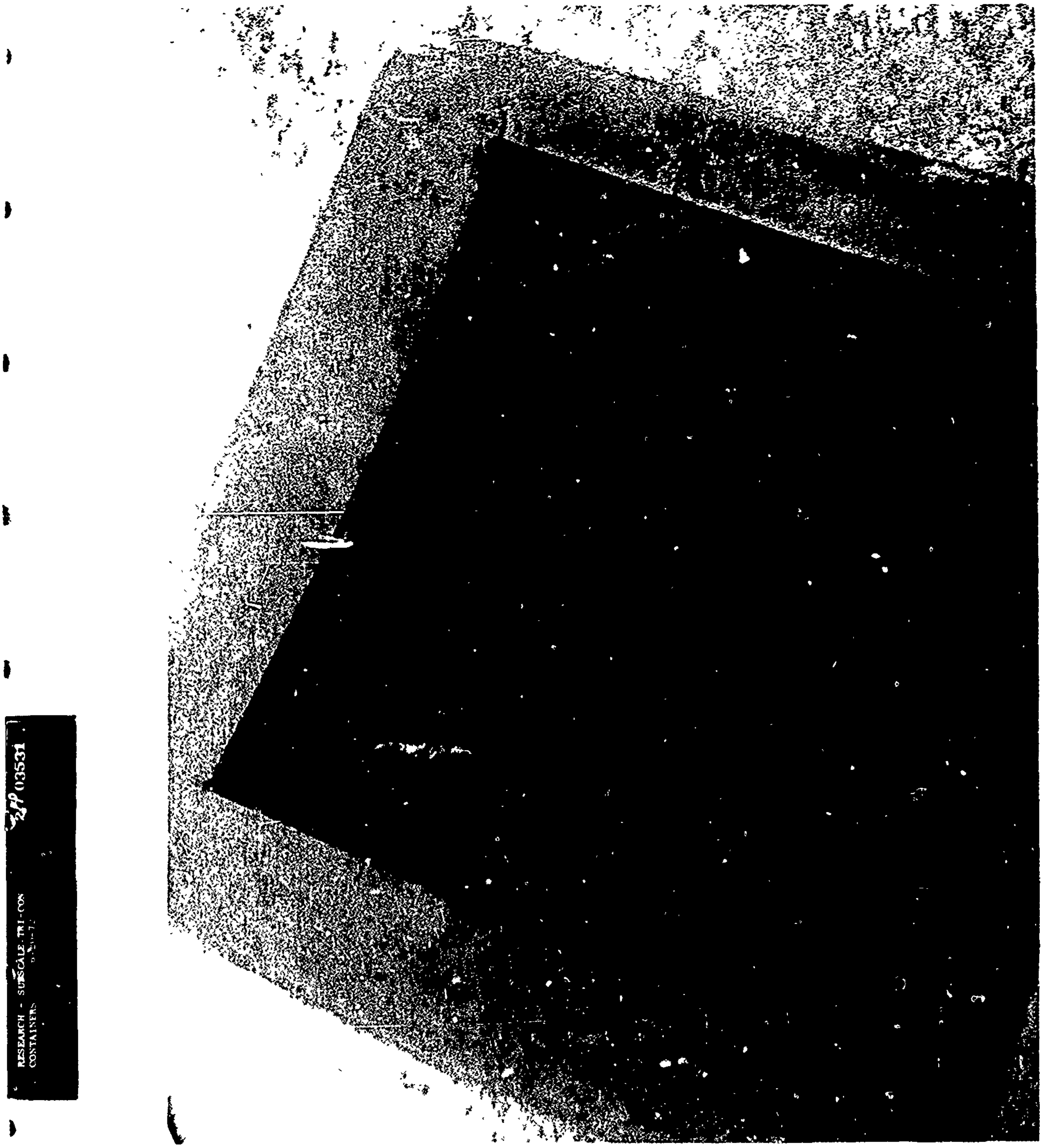


FIGURE 56

STRESS CRACKS IN CROSSLINKED POLYETHYLENE
ENCAPSULATING ALUMINUM INSERTS

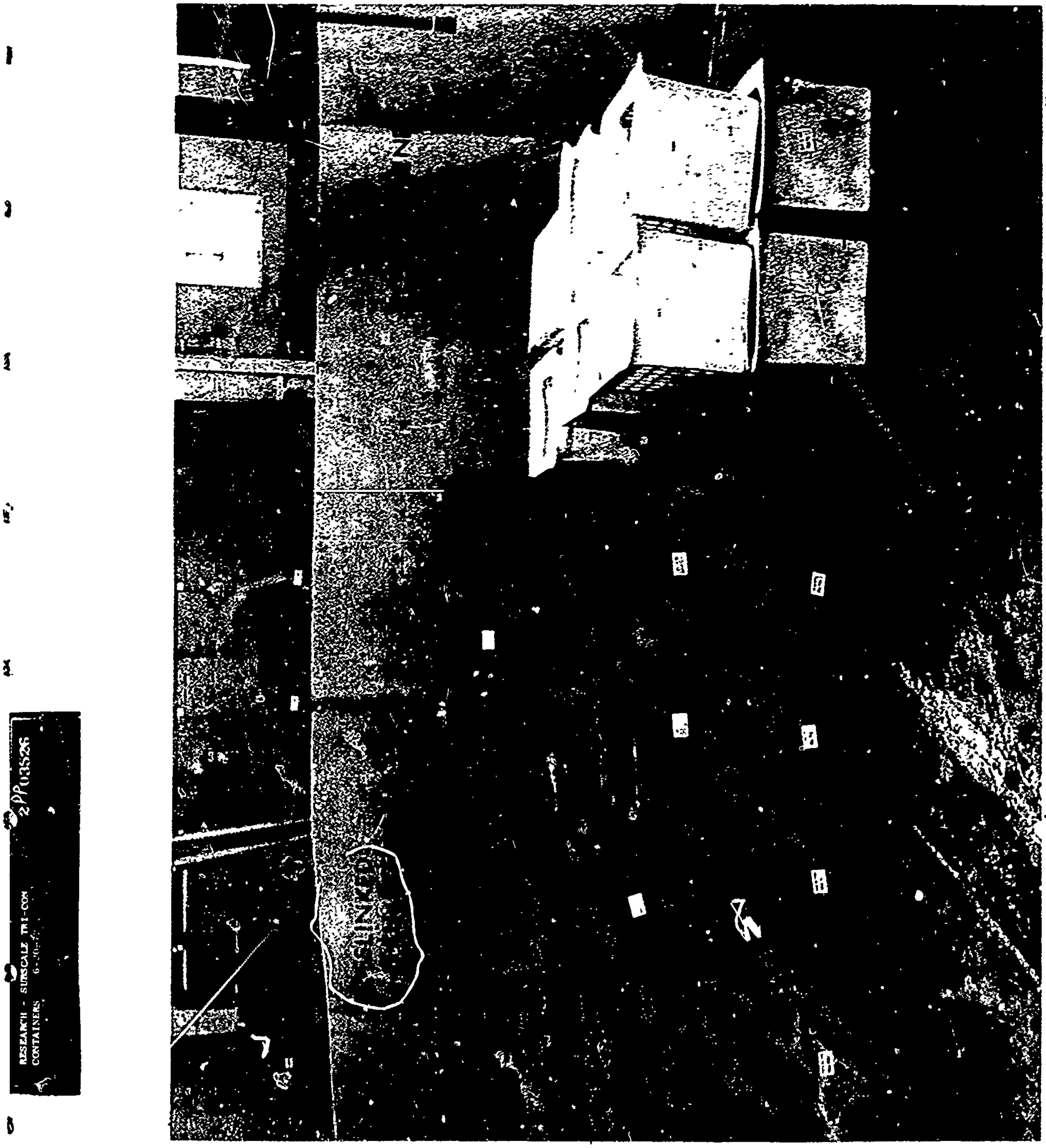


FIGURE 57

PARTS MOLDED DURING PROCESS OPTIMIZATION STUDIES

Three specimens of each were rotational molded to encapsulate them with plastic. The specimens were then tested for shear strength using the Porta-Shear equipment shown in Figure 58.

Porta-Shear is a semi-destructive method for evaluating the shear strength of metal-to-metal adhesive bonds. The equipment consists of three units: a cutter assembly, a shear head, and a pneumatic regulating device. The cutter assembly consists of a controlled depth hollow cutter which is used for preparing the specimen by cutting away an annular ring completely through the outer face sheet and into the adhesive material, leaving a 1/4 inch diameter button (Figure 59) to which the shear head is applied. The shear head applies a shear force to the test button and the pneumatic regulator supplies compressed air at a predetermined constant rate, ensuring that the specimen is loaded gradually. The Porta-Shear system is calibrated so that the gauge reading times 100 equals the shear force in psi at the test specimen.

Tests were conducted on specimens encapsulated with crosslinked polyethylene, crosslinked polyethylene blended with 2% chopped fiberglass, and high density polyethylene. The test results shown in Figure 60 indicate that only aluminum, sandblasted and cleaned with MEK before encapsulation, produced a good bond with all three plastics tested. The results obtained with other test specimens showed an inconsistent pattern. For example, sandblasted and solvent cleaned steel produced a bond of 800 psi shear strength with crosslinked polyethylene, and no measurable bond with the other two plastics.

It was concluded from these tests that sandblasting and solvent cleaning aluminum was the most reliable surface cleaning method and metal selection for the achievement of a good plastic-metal bond.

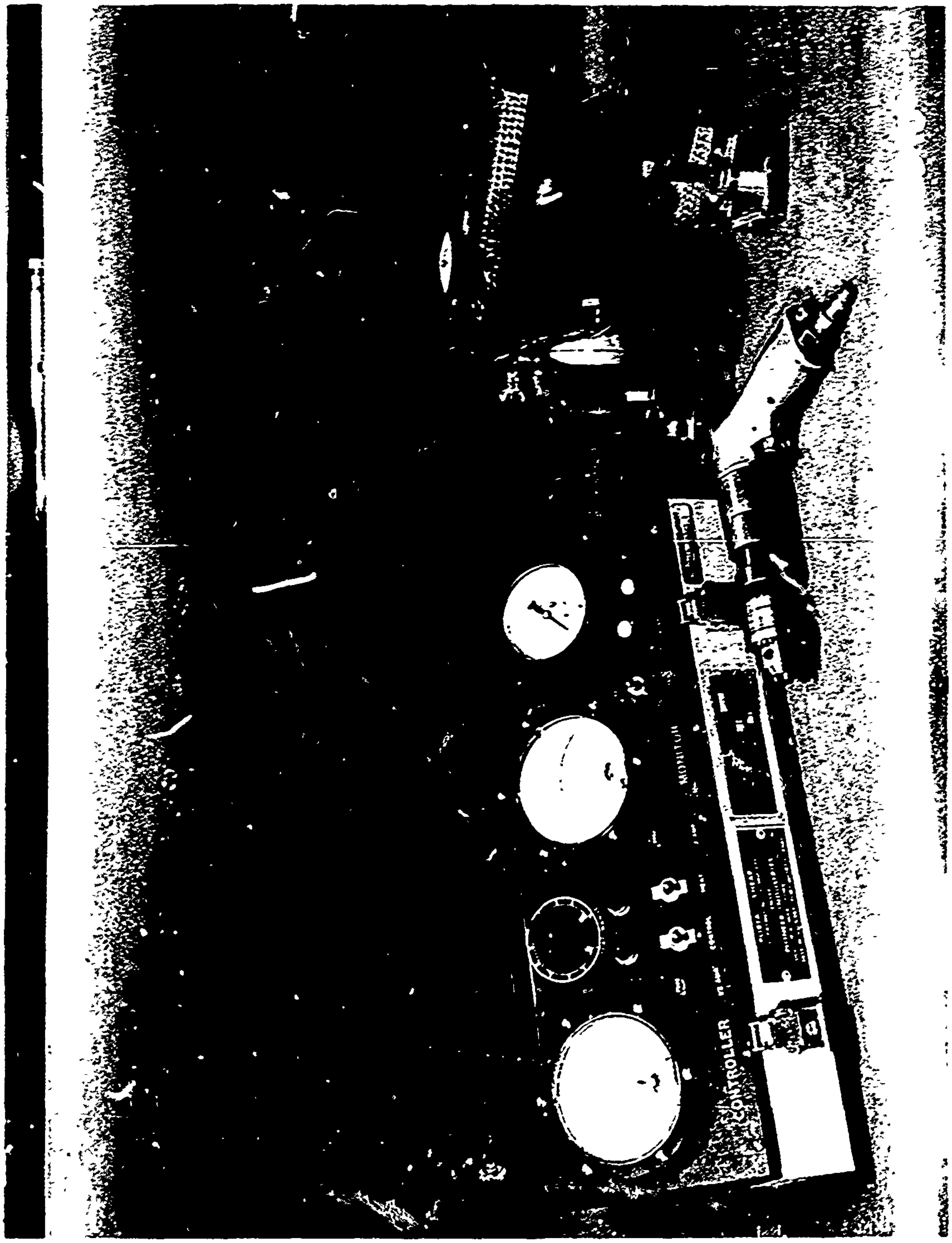


FIGURE 58

"PORTA-SHEAR" SHEAR STRENGTH TEST EQUIPMENT

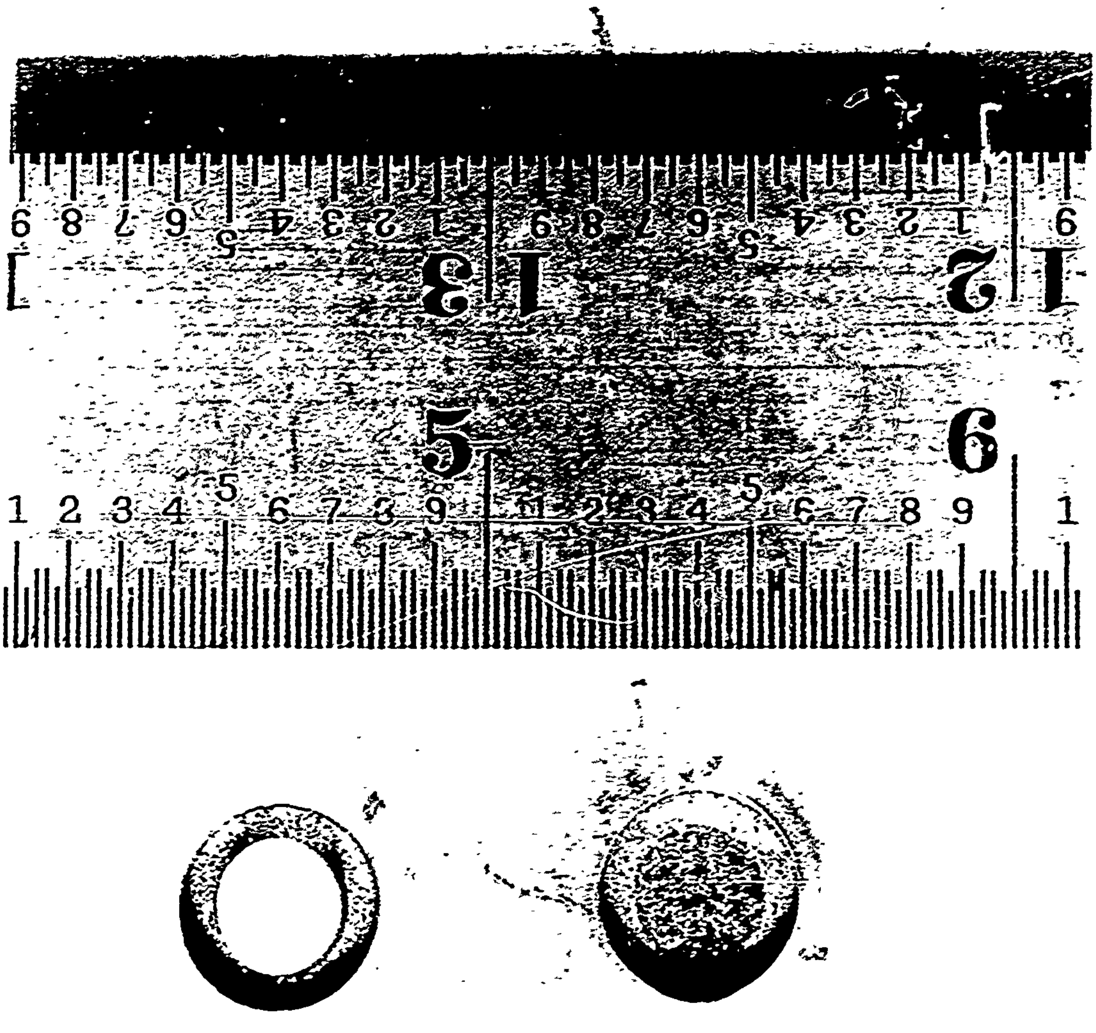


FIGURE 59

TYPICAL PORTA-SHEAR TEST BUTTON

ENCAPSULATING MATERIAL	SHEAR STRENGTH, PSI					
	ALUMINUM			STEEL		
	SOLVENT CLEAN ONLY	SANDBLAST AND SOLVENT CLEAN	SANDBLAST, SOLVENT CLEAN AND PRIMED	SOLVENT CLEAN ONLY	SANDBLAST AND SOLVENT CLEAN	SANDBLAST, SOLVENT CLEAN AND PRIMED
Crosslinked Polyethylene	NMB*	1350	NMB*	400	800	200
Crosslinked Polyethylene and 2% Fiberglass	NMB*	1100	400	NMB*	NMB*	1200
High Density Polyethylene	NMB*	1000	NMB*	NMB*	NMB*	NMB*

* No Measurable Bond

FIGURE 60

ADHESION TEST RESULTS

4.0 DISCUSSION

The feasibility of encapsulating a perforated metal insert with crosslinked polyethylene using the rotational molding process was demonstrated during the program, thereby accomplishing the initial objective of the program. However, when a framework of sufficient strength to meet the design load objectives was incorporated into the design, attempts to encapsulate subscale frameworks, both steel and aluminum, were unsuccessful.

Although many avenues and approaches were explored, three problems persisted throughout the program. They were (1) the elimination of stress cracks, (2) achievement of thorough encapsulation, and (3) a strong plastic-metal bond. The data generated during the program and reported in the preceding sections present a paradoxical situation. For example:

A. Test data generated early in the program indicated that shrinkage of the plastic (thought to be the cause of the stress cracks) could be significantly reduced by shortening the cooling time. However, in actual experience with the subscale containers, the mass of the metal mold, framework, and plastic could not be cooled at a sufficient rate to reduce the shrinkage.

   The container framework was first designed in steel. When the problem of cracks was recognized, the steel container and mold were therefore redesigned in aluminum to improve the thermal conductivity and reduce the inherent mass. However, tests conducted with an aluminum subscale mold and framework were also unsuccessful.

B. The encapsulation studies indicate that the maximum metal width that could be encapsulated was 1-1/2 inch. In order to meet the design load requirements of the full size TRICON, design calculations indicated that corner posts must be at least 4 inches wide. It is apparent that with existing technology and equipment, it is not possible to encapsulate a full size TRICON framework that would meet the strength requirements of this program.

C. It was demonstrated during the program that the nominal shrinkage of a rotational molded plastic can be significantly reduced by the addition of chopped fiberglass strands. From the test program it was apparent that the addition of fiberglass filler altered the flow characteristics of the plastic. As a general rule, the higher the percentage of filler the worse the flow characteristics become. It was found during the encapsulation studies that the plastic-fiberglass blend would not flow sufficiently to encapsulate the metal insert.

It should be noted that this program did produce a substantial body of original data related to the rotational molding process and rotational molding grade plastics. This data not only advances the state-of-the-art, but can be used to advantage by the plastics industry in general. The original information generated under this program is as follows:

1. Comparative evaluations of parting agents for the rotational molding process.

2. Molding characteristics of rotational molding grade plastics.

3. Studies on preparation of metal surfaces to achieve a good adhesive bond with rotational molded plastics.

4. Encapsulation studies, including data on web-opening relationships, mold-insert spacing, and molding cycles covering a variety of thermoplastic materials and plastic-fiberglass blends.

5. Techniques for rotational molding blends of plastics and chopped fiberglass strands.

6. Shrinkage versus percent of fiberglass curves for a variety of rotational molding grade plastics.

7. Shrinkage versus cooling rate curves for a variety of rotational molding grade plastics.

5.0 CONCLUSIONS

As a result of the work conducted under this program, the following conclusions have been made:

1. With existing state-of-the-art technology and rotational molding equipment, there is a low probability of successfully encapsulating a full size TRICON meeting the requirements of MIL-C-52661(ME). While it has been shown that it is possible to encapsulate small perforated metal panels, it has been amploy demonstrated that the technology is not available at this time for encapsulating a structural framework in combination with similar panels.

2. Of the release agents evaluated, the Ram GS-3 fluorocarbon produced the best surface finish on the molded part.

3. The CL-100 crosslinked polyethylene proved to be the most easily molded and best suited to the encapsulation of metal inserts.

4. The nominal shrinkage of a rotational molded plastic can be reduced by the addition of chopped fiberglass strands.

5. The nominal shrinkage of a rotational molded plastic can be reduced by increasing the cooling rate of the molding cycle.

6. The addition of chopped fiberglass strands to crosslinked polyethylene alters the flow characteristics of the plastic sufficiently to prevent encapsulation of a metal insert.

7. Aluminum, sandblasted and solvent cleaned, produced the best adhesive bond with all three plastics tested.

8. The program was successful in developing a body of original information on the rotational molding process and rotational molding grade plastics. This information advances the state-of-the-art and benefits the plastic industry as a whole.

6.0 RECOMMENDATIONS

The following recommendations are made as a result of work completed under this contract:

1. That no further attempt be made at this time to develop the capability of rotational molding a plastic TRICON container by encapsulating a metal framework.

2. That alternative approaches to the development of plastic TRICON containers be considered.

3. That the body of information generated during this program be published, thereby advancing the plastics industry state-of-the-art.

APPENDIX A

FABRICATION TRADE STUDY FOR STEEL TRICON
STRUCTURAL SECTIONS

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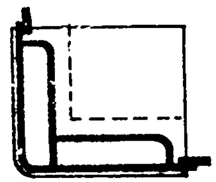
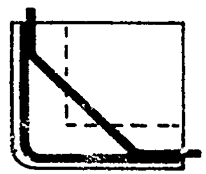
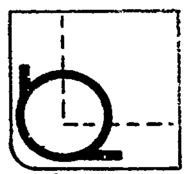
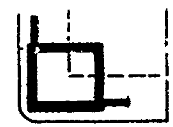
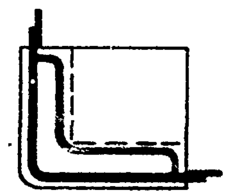
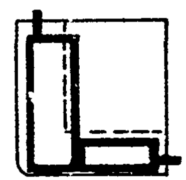
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	MERIT INDEX ** LABOR COST (Cutting-Welding-Forming)	MERIT INDEX ** COST/LIN FT.
1	BASELINE CORNER POST CONFIGURATION		1.0	1.0	1.0
2	FABRICATED PLATE CORNER POST		.97	.60	.77
3	ROUND TUBE CORNER POST		1.25	.47	.825

* Cost comparisons based on equivalent strength and weight values

** Rating method: Index numbers lower than one (1) represent ratio of cost improvement over base line configuration.

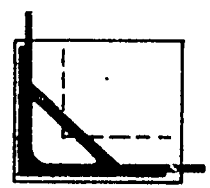
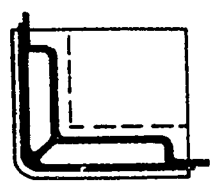
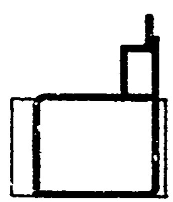
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	LABOR COST (Cutting-Welding-Forming)	COST/LIN FT.
4	SQUARE TUBE CORNER POST		1.23	.47	.83
5	FABRICATED PLATE CORNER POST		1.04	1.06	1.05
6	RECTANGULAR TUBES CORNER POST		1.30	.87	1.06

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration.

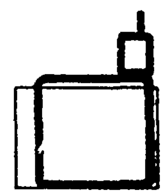
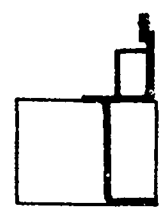
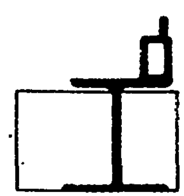
FABRICATION TRADE STUDY FOR STEFL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	MERIT INDEX ** LABOR COST (Cutting-Welding-Forming)	MERIT INDEX ** COST/LIN FT.
7	ANGLE CORNER POST		1.55	1.06	1.28
8	EXTRUDED SECTION CORNER POST		5.30	.27	2.54
9	BASELINE BLIND SIDE LOWER RAIL (FABRICATED)		1.0	1.0	1.0

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration.

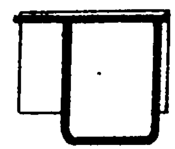
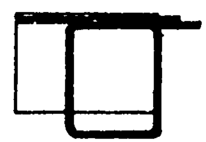
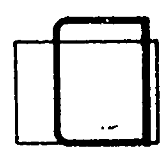
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	LABOR COST (Cutting-Welding-Forming)	COST/LIN FT.
10	BLIND SIDE LOWER RAIL RECT. TUBE		1.19	.78	.96
11	BASELINE R.H. AND L.H. END LOWER RAIL		1.0	1.0	1.0
12	R.H. AND L.H. END LOWER RAIL		1.15	1.35	1.24

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration.

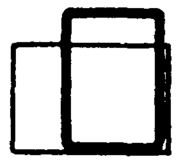
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	MERIT INDEX ** LABOR COST (Cutting-Welding-Forming)	MERIT INDEX ** COST/LIN FT.
13	BASELINE DOOR HEADER		1.0	1.0	1.0
14	DOOR HEADER RECT. TUBE		1.33	1.1	1.22
15	BASELINE DOOR SILL		1.0	1.0	1.0

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration.

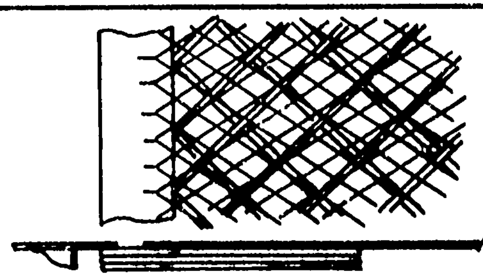
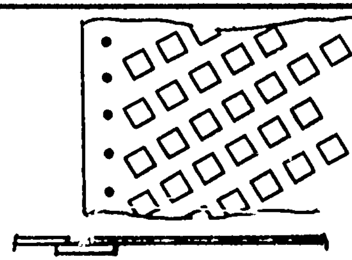
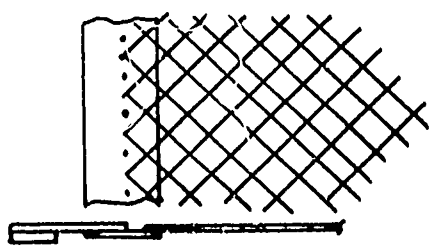
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	LABOR COST (Cutting-Welding-Forming)	COST/LIN FT
16	DOOR SILL RECTANGULAR TUBE		1.12	.67	.93
17	BASELINE DOOR POST		1.0	1.0	1.0
18	DOOR POST TUBE/PLATE		1.14	1.0	1.06

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over base line configuration.

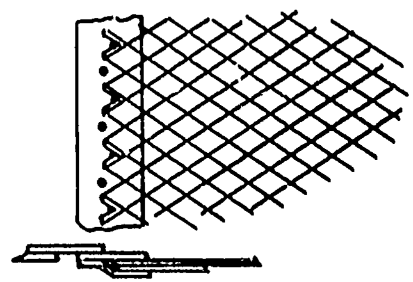
FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

			MERIT INDEX **		
NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MATERIAL COST	LABOR COST (Cutting-Welding-Forming)	COST/SQ..FT..
19	BASELINE PANEL WIRE MESH + TIE RODS		1.0	1.0	1.0
20	PUNCHED PLATE PANEL		.38	1.4	.65
21	HIGH STRENGTH WIRE BRAZED AT EDGING		1.06	1.75	1.22

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration,

FABRICATION TRADE STUDY FOR STEEL TRICON STRUCTURAL SECTIONS *

NO.	SECTION DESCRIPTION	CONFIGURATION SKETCH	MERIT INDEX ** MATERIAL COST	MERIT INDEX ** LABOR COST (Cutting-Welding-Forming)	MERIT INDEX ** COST/SQ. FT.
22	HIGH STRENGTH WIRE MECHANICALLY JOINED AT EDGING		1.06	2.2	1.35

* Cost comparisons based on equivalent strength and weight values.

** Rating Method: Index numbers lower than one (1) represent ratio of cost improvement over baseline configuration.

APPENDIX B

BASIC DESIGN CALCULATIONS FOR STEEL CONTAINER ELEMENTS

INDEX TO APPENDIX B

INTRODUCTION

When determining the fabrication methods to be used on the subscale container it was necessary to select a variety of posts and rails.

The side walls were fabricated to different designs for the purpose of determining the best molding design.

Two standard corner castings were incorporated to provide data on molding around large masses of material.

The balance of the structure was assembled in the lightest manner to avoid overloading our McNeil-Akron-McNeil molding machine which was to be used in test molding.

For details of the actual structure used in the subscale, see drawing R677069PO2.

The Boeing Engineering Stress Unit made a preliminary review of the subscale container concept, extrapolating the data to full size. No final margin of safety was used in the analysis. The material used was a steel used in Boeing Aerospace ground equipment which would support the design loads without permanent deformation. The Stress unit reply (Appendix I) demonstrates that the design objectives have been met. It also stated that the use of higher strength materials would permit a reduction of size in some sections.

An estimated weight of Boeing Tricon containers was made using the Weyerhauser Tricon as a base. The assumption that the Weyerhauser structure less side walls would be similar to the Boeing unit.

The rotomolded panels with plastic were added to the structure weight. The average weights shown include 420 pounds of molding plastic for containers with molded doors and 370 pounds of plastic for containers with plywood doors.

A.	Punched plate panels plywood doors	2456 pounds
B.	Tierod/mesh panels plywood doors	2503 pounds
C.	Punched plate panels, molded doors	2621 pounds
D.	Tierod/mesh panels, molded doors	2668 pounds

The Weyerhouser containers with FRP panels and plywood doors weighed 1960 pounds. They did not contain two features which are included in the Boeing containers. These features are side fork lift pockets and internal tie downs, which added 79 pounds.

DESIGN OBJECTIVES

TYPE LOAD		UNIT AND LOAD
Stacking	S	Load test 77-1/2" unit 60 26,879 lb. gross weight. Apply 100,800 lb. vertical load S to each top corner fitting in turn. Load S = 100,800 lb.
Lifting From Top	T	Couple three 77-1/2" units together. Load to total gross weight of 89,600 lb. Lift by the four top corner fittings using hooks in end holes or side holes. Load T = 22,400 lb.
Lifting From Bottom	L	Couple three 77-1/2" units together. Load to total gross weight of 89,600 lb. Attach sling to side holes in bottom corner fitting with line of action at 30° to the horizontal, and lift. Load L = 22,400/sine 30° = 44,800 lb. Vertical component - 22,400 lb., horizontal component - 39,000 lb.
Horizontal Restraint	B	Couple three 77-1/2" units together. Load to total gross weight of 44,800 lb. Apply a compression load B and then a tension load to each lower side rail in turn. Load B = (1.25) (gross weight) = 56,000 lb.
Floor Load		(1) Load floor to a uniformly distributed load of 30,000 lb. (2) Load floor to a concentrated load of 6,000 lb. over an area 3" x 7-1/3".
Roof Load		Load roof to 660 lb. uniformly distributed over a 12" x 24" area.
Wall Side Load	W	(1) Apply a uniformly distributed load of 5,460 lb. to either the R.H. or L.H. end wall. (2) Apply a uniformly distributed load of 8,100 lb. to the door side and the blind side in turn.
Racking	R	Restrain container through bottom corner fittings. Apply a compression and a tension load laterally and longitudinally in turn of 35,000 lb. to each top corner fitting in turn.

TRICON

PRELIMINARY ANALYSIS

THE ANALYSIS WAS PERFORMED IN ORDER TO DETERMINE THE FEASIBILITY OF THE TYPE OF CONSTRUCTION, CHECK THE PROPOSED SIZING, AND MAKE GENERAL RECOMMENDATIONS CONCERNING THE STRUCTURAL CONFIGURATION. IT IS INTENDED AS A PRELIMINARY ANALYSIS ONLY.

TRICON

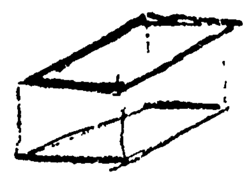
RECOMMENDATIONS

1) USE STIFFENERS ON BEAMS AT EDGES OF FORKLIFT CUTOUTS.

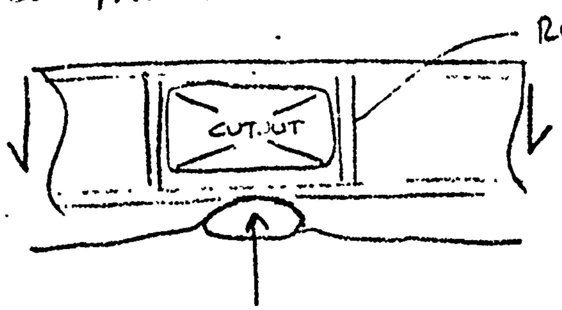
2) USE SYMMETRICAL "I" SECTION FOR FLOOR BEAMS.

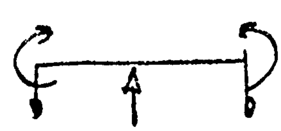
3) MATERIALS

MEMBER	F_{TY} OR F_{CY} (MIN)
DOOR SIDE POST	100.
BLIND SIDE POST	75.
DOOR UPPER SILL	30.
DOOR LOWER SILL	30.
BLIND SIDE UPPER SILL	36.
BLIND SIDE LOWER SILL	36.
UPPER SIDE RAIL	36.
LOWER SIDE RAIL	100.0
FLOOR BEAM	75.0
SIDE WALL	75.0
BLIND SIDE WALL	75.0



4) THE MEMBERS ABOVE AND BELOW THE FORKLIFT CUTOUTS APPEAR TO BE VERY EASILY DAMAGED BY WILD FORKLIFT DRIVERS OR SETTING A LOADED CONTAINER ON UNEVEN GROUND.



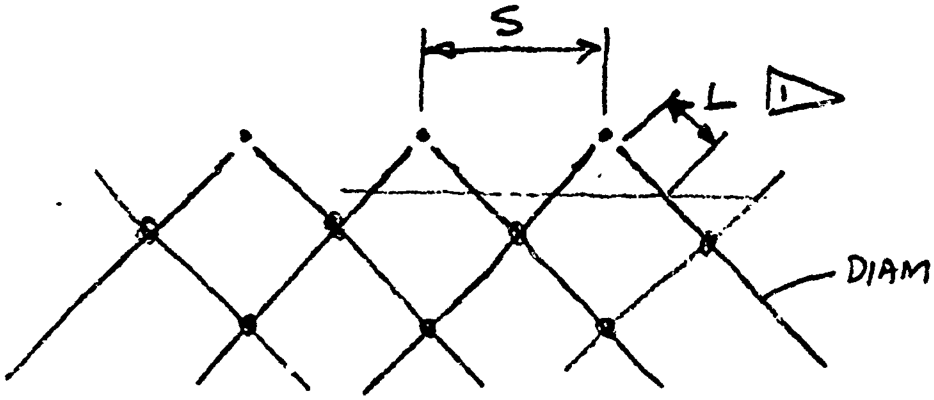


RECOMMEND STIFFENING THESE ELEMENTS.

TRICON

RECOMMENDATIONS

5) THE STRAP EFFECTIVETY IN COMPRESSION SIGNIFICANTLY REDUCES THE TRANSVERSE LOADS ON THE EDGE MEMBERS. IF THE STRAPS ARE FULLY EFFECTIVE IN COMPRESSION, THE TRANSVERSE LOAD IS ELIMINATED ENTIRELY. IT IS THEREFORE RECOMMENDED THAT ONE OF THE FOLLOWING CONFIGURATIONS BE USED.



1 L SHOULD BE WELDED BOTH SIDES TO DEVELOP ULTIMATE STRENGTH OF ROD

DIAM	S
3/16	4.40"
1/4	6.50"

IT APPEARS THAT APPROXIMATELY 200#/TRICON CAN BE SAVED USING THE 3/16" DIAMETER, THEREFORE IT IS RECOMMENDED.

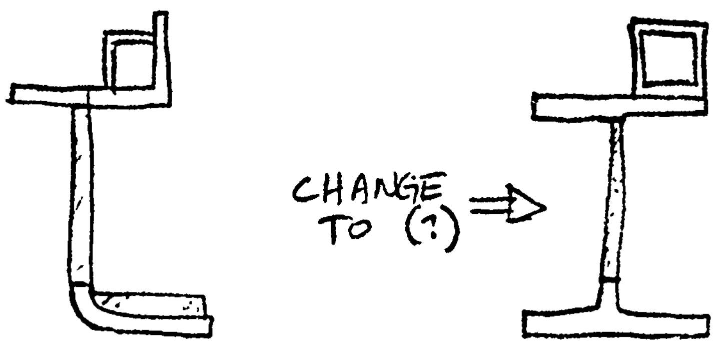
TRICON

RECOMMENDATIONS

6) THE ANALYSIS OF THE POSTS IS INCOMPLETE IN THAT THE EFFECT OF THE DOOR ON STABILIZING THE DOOR POSTS IS NOT INCLUDED. A MORE EXTENSIVE ANALYSIS WOULD BE REQUIRED.

7) IF THE STRUCTURE IS RECONFIGURED, I.E. MEMBER CROSS SECTIONS ARE REVISED OR RELOCATED THEY CAN BE MADE MORE EFFICIENT. THE DESIGN IS SENSITIVE TO ECCENTRICITIES, PARTICULARLY WITH THE LARGE AMOUNT OF WELDING UTILIZED.

8) LOWER SIDE RAIL SHOULD PROBABLY BE STIFFENED IF THE STRUCTURE IS RECONFIGURED.



9) THE DEFORMATION IN THE DOOR CUTOUT COULD BE A PROBLEM WHEN THE RACKING LOAD IS APPLIED IN THE PLANE OF THE DOOR. THE DATA ON HINGES, LATCHES, AND DOOR STRUCTURE WAS NOT AVAILABLE

TRKON

RECOMMENDATIONS

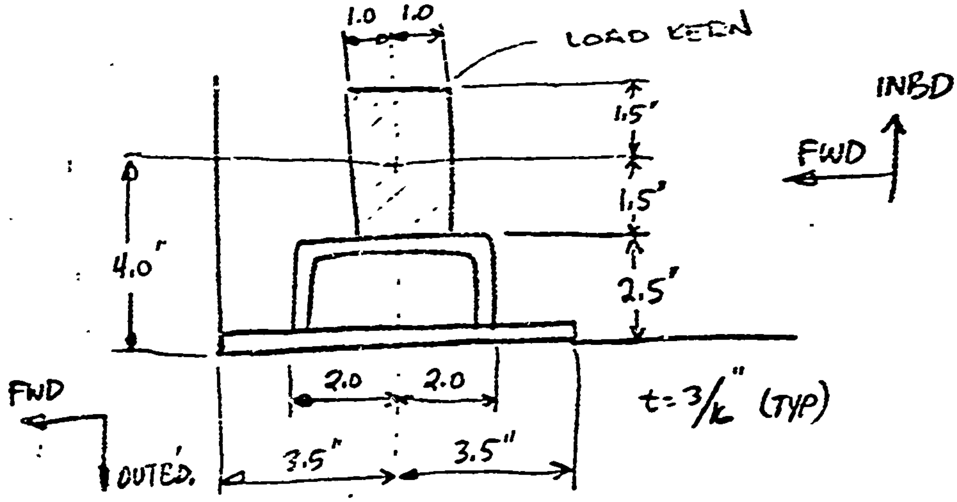
10) WEIGHT REDUCTIONS ARE POSSIBLE IF HIGHER STRENGTH STEELS ARE UTILIZED IN THOSE MEMBERS REQUIRING A MINIMUM YIELD STRESS OF 40.0 KSI OR LOWER (SEE RECOMMENDATION 3). THE AMOUNT OF WEIGHT SAVED WILL NOT BE PROPORTIONAL TO THE STRESS LEVEL SINCE SOME STRUCTURE IS STIFFNESS DESIGNED.

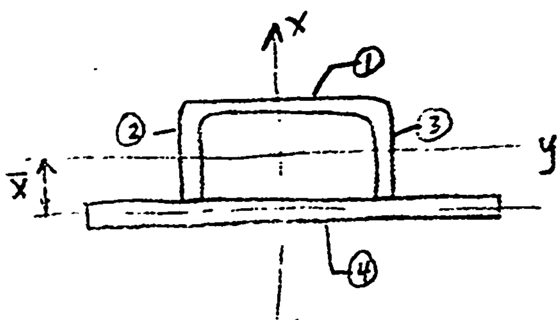
A MORE REFINED ANALYSIS THAT ACCURATELY ACCOUNTS FOR THE INTERACTION BETWEEN THE MEMBERS AND THE RELATIVE STIFFNESS OF THE MEMBERS COULD RESULT IN FURTHER WEIGHT REDUCTIONS.

11) A REVIEW OF THE MAINTENENCE REQUIREMEN SHOULD BE PERFORMED BY MATERIALS GROU THE PROBLEM OF RUSTING, PAINTING, AND HANDLING DAMAGE MUST BE CONSIDERED IN TI MATERIAL SELECTION.

TRICON

DOOR SIDE POST





ELEM	A	x	Ax	Ax^2	I_x	I_y
1	.75	2.0	1.50	3.00	1.01	.25
2	.375	1.0	.375	.375	0	0
3	.375	1.0	.375	.375	0	0
4	1.32	0	0	0	5.40	.25
	2.82		2.25	3.75	0	.50

$$\bar{X} = \frac{2.25}{2.82} = .80''$$

$$I_y = \Sigma A x^2 - \Sigma A (\bar{x})^2 = 2.45 \text{ IN}^4$$

$$I_x = \Sigma I_x = 6.40 \text{ IN}^4$$

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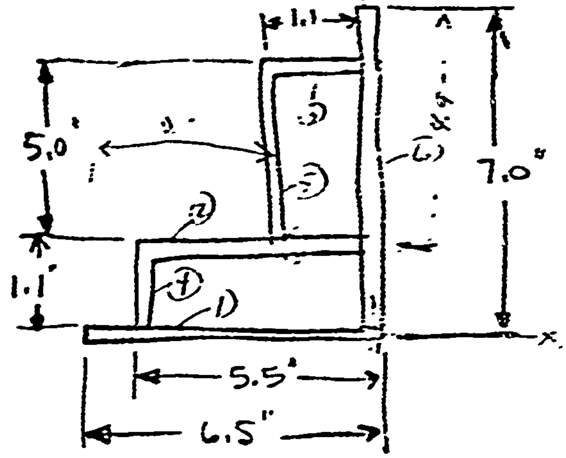
TRICON

BLIND SIDE POST



ELEM	A	x	Ax	Ax²	y	Ay	Ay²	Ix	Iy
1	1.22	-3.25	-3.97	12.9	0	0	0	0	4.35
2	1.03	-2.75	-2.83	7.8	1.1	1.13	1.25	0	2.63
3	.20	-.6	-.12	.0	6.1	1.22	7.45	0	0
4	.20	-5.5	-1.10	6.1	.6	.12	0	0	0
5	.94	-1.1	-1.03	1.1	3.6	3.39	12.20	1.98	0
6	1.31	0	0	0	3.5	4.59	16.00	5.43	0
	4.90		-9.05	27.9		10.45	36.90	7.41	6.98

$$\bar{x} = \frac{-9.05}{4.90} = -1.85$$

$$I_y = \Sigma I_y + Ax^2 - \Sigma A(\bar{x})^2 = 6.98 + 27.9 - \overset{34.9}{16.8} = 18.1 \text{ IN}^4$$

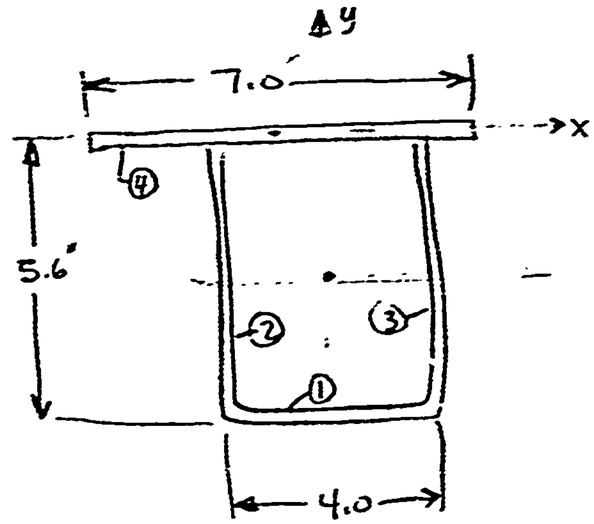
$$\bar{y} = \frac{10.45}{4.90} = 2.13$$

$$I_x = \Sigma I_x + Ay^2 - \Sigma A(\bar{y})^2 = 7.41 + 36.9 - 4.9(2.13)^2 = 22.1 \text{ IN}^4$$

44.3
22.2

TRICON

DOOR HEADER



$t = 3/16$" TYP

ELEM	A	x	y	Ax	Ax^2	Ay	Ay^2	I_x	[illegible]
1	.75	0	-5.4	0	0	-4.05	21.9	0	5
2	.98	-2.0	-2.2	-1.96	3.92	-2.16	4.76	2.35	
3	.98	2.0	-2.2	+1.96	3.92	-2.16	4.76	2.35	
4	1.31	-.5	0	-.61	.30	0	0	0	1
	4.02			-.61	8.14	-8.37	31.42	4.70	[illegible]

$$\bar{x} = \frac{\Sigma Ax}{\Sigma A} = \frac{-.61}{4.02} = -.15$$

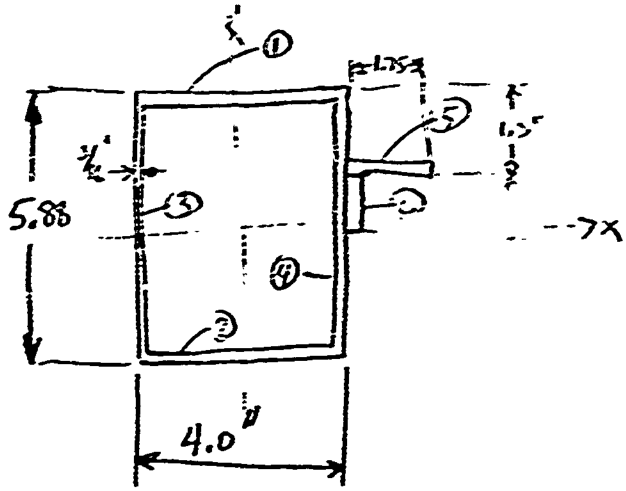
$$I_y = \Sigma I_y + Ax^2 - \Sigma A(\bar{x})^2 = 6.41 + 8.14 - 4.02(.15)^2 = 14.46 \text{ in}^4$$

$$\bar{y} = \frac{\Sigma Ay}{\Sigma A} = \frac{-8.37}{4.02} = -2.07"$$

$$I_x = \Sigma I_x + Ay^2 - \Sigma A(\bar{y})^2 = 4.70 + 31.4 - 4.02(-2.07)^2 = 18.7 \text{ in}$$

TRICON

DOOR SILL



ELEM	A	x	Ax	Ax²	y	Ay	Ay²	I_x	I_y
1	.75	0	0	0	2.85	2.14	6.10	0	1.00
2	.75	0	0	0	-2.85	-2.14	6.10	0	1.00
3	1.10	1.8	1.98	3.56	0	0	0	2.80	0
4	1.10	-1.8	-1.98	3.56	0	0	0	2.80	0
5	.33	2.88	.95	2.74	1.80	.59	1.06	0	0
6	.24	2.09	.50	1.04	1.10	.26	.29	0	0
	4.27		1.45	10.90		.85	13.55	5.60	2.00

$$\bar{x} = \frac{\Sigma Ax}{\Sigma A} = \frac{1.45}{4.27} = .34''$$

$$I_y = \Sigma I_y + \Sigma Ax^2 - \Sigma A(\bar{x})^2 = 2.00 + 10.9 - 4.27(.34)^2 = 12.40 \text{ IN}^4$$

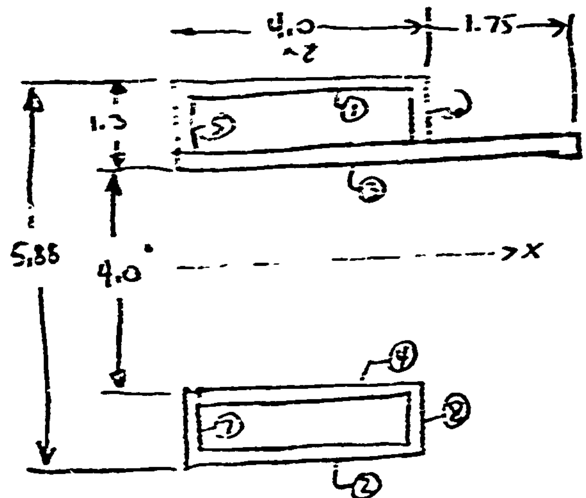
$$\bar{y} = \frac{.85}{4.27} = .20''$$

$$I_x = 5.60 + 13.55 - (4.27)(.20)^2 = 19.00 \text{ IN}^4$$

JJT 4-27-71

TRICON

DOOR SILL (@ FORKLIFT POCKET)



ELEM	A	x	AX	Ax^2	y	Ay	Ay^2	I_x	I_y
1	.75	0	0	0	2.85	2.14	6.10	0	1.00
2	.75	0	0	0	-2.85	-2.14	6.14	0	1.00
3	1.08	.88	.95	.84	2.09	2.25	4.70	0	3.00
4	.75	0	0	0	-2.09	-1.56	3.25	0	1.00
5	.17	-1.88	-.32	.60	2.65	+.45	1.19	0	0
6	.17	1.88	.32	.60	+2.65	+.45	1.19	0	0
7	.17	-1.88	-.32	.60	-2.65	-.45	1.19	0	0
8	.17	1.88	.32	.60	-2.65	-.45	1.19	0	0
	4.01		.95	3.24		.70	24.95	0	6.00

$$\bar{x} = \frac{.95}{4.01} = .236$$

$$I_y = 6.00 + 3.24 - 4.01(.236)^2 = 9.00 \text{ IN}^4$$

$$\bar{y} = \frac{.70}{4.01} = .175$$

$$I_x = 0 + 24.95 - 4.01(.175)^2 = 24.83 \text{ IN}^4$$

TRICON

DOOR SILL (UPPER Pressed Beam @ FORK LIFT POCKET)

(USE ELEMENTS 1, 3, 5, & 6 FROM PREVIOUS CALC'S)

ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	I_x	I_y
1	.75	0	0	0	2.85	2.14	6.10	0	1.00
3	1.08	.88	.95	.84	2.09	2.26	4.70	0	3.00
5	.17	-1.88	-.32	.60	2.65	.45	1.19	0	0
6	.17	1.88	.32	.60	2.65	.45	1.19	0	0
	2.17		.95	2.04		5.30	13.18	0	4.00

$\bar{X} = \frac{.95}{2.17} = .44$ in

$I_y = 4.00 + 2.04 - 2.17(.44)^2 = 5.62$ in^4

$\bar{y} = \frac{5.30}{2.17} = 2.44$ in

$I_x = 0 + 13.18 - 2.17(2.44)^2 = 0.3$ in^4

DOOR SILL (LOWER BEAM @ FORK LIFT POCKET)

(USE ELEMENTS 2, 4, 7, & 8 FROM PREVIOUS CALCS)

ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	I_x	I_y
2	.75	0	0	0	-2.85	-2.14	6.14	0	1.00
4	.75	0	0	0	-2.09	-1.56	3.25	0	1.00
7	.17	-1.88	-.32	.60	-2.65	-.45	1.19	0	0
8	.17	1.88	.32	.60	-2.65	-.45	1.19	0	0
	1.84		0	1.20		-4.60	11.77	0	2.00

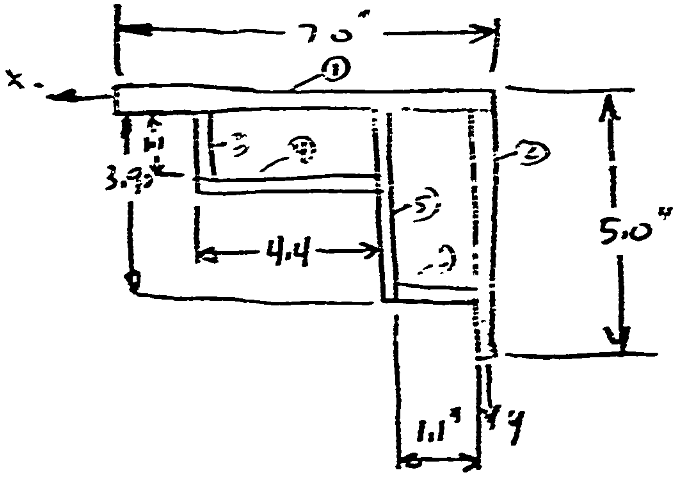
$\bar{X} = 0 \qquad I_y = 2.00 + 1.20 = 3.20$ in^4

$\bar{y} = \frac{-4.60}{1.84} = -2.50$

$I_x = 0 + 11.77 - 1.84(2.50)^2 = .27$ in^4

TRILON

BLIND SIDE TOP RAIL



ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	Ix	Iy
1	1.32	3.45	4.55	15.70	0	0	0	0	5.43
2	.94	0	0	0	2.45	2.30	5.63	1.90	0
3	.21	5.70	1.20	6.85	.70	.14	.10	0	0
4	.83	3.60	3.00	10.80	1.35	1.12	1.51	0	1.35
5	.73	1.30	.95	1.24	2.00	1.46	2.92	.94	0
6	.21	.70	.15	.10	3.90	.82	3.20	0	0
	4.24		9.85	34.69		5.84	13.36	2.84	6.78

$$\bar{x} = \frac{9.85}{4.24} = 2.33$$

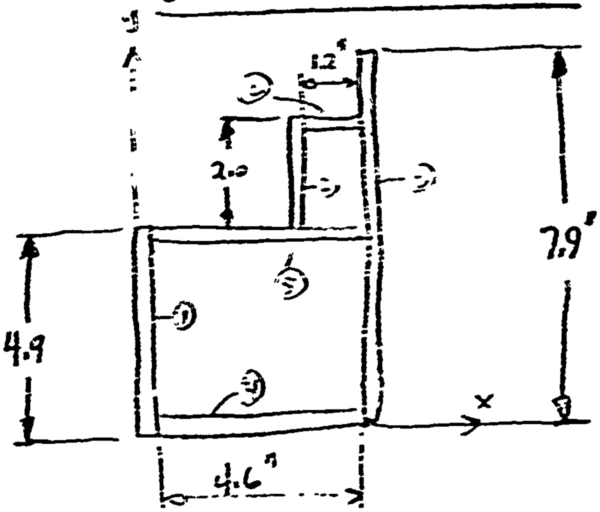
$$I_y = \Sigma I_y + Ax^2 - \Sigma A(\bar{x})^2 = 6.78 + 34.69 - 4.24(2.33)^2 = 18.57 \text{ IN}$$

$$\bar{y} = \frac{5.84}{4.24} = 1.38$$

$$I_x = \Sigma I_x + Ay^2 - \Sigma A(\bar{y})^2 = 2.84 + 13.36 - 4.24(1.38)^2 = 8.10 \text{ IN}$$

TRICON

BLIND SIDE BOTTOM RAIL



ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	I_x	I_y
1	.92	0	0	0	2.35	2.16	5.09	1.87	0
2	.37	3.45	1.28	4.40	5.80	2.15	12.50	.13	0
3	1.48	4.80	7.10	34.10	3.95	5.83	23.10	7.80	0
4	.86	2.40	2.06	4.96	0	0	0	0	1.54
5	.86	2.40	2.06	4.96	4.70	4.04	19.00	0	1.54
6	.22	4.10	.90	3.70	6.85	1.50	10.20	0	0
	4.71		13.40	52.12		15.68	69.89	9.80	3.08

$$\bar{X} = \frac{13.4}{4.71} = 2.85''$$

$$I_y = \Sigma I_y + \Sigma Ax^2 - \Sigma A(\bar{X})^2 = 3.08 + 52.12 - 4.71(2.85)^2 = 17.1 \text{ IN}^4$$

$$\bar{y} = \frac{15.68}{4.71} = 3.34''$$

$$I_x = \Sigma I_x + \Sigma Ay^2 - \Sigma A(\bar{y})^2 = 9.80 + 69.89 - 4.71(3.34)^2 = 27.4 \text{ IN}^4$$

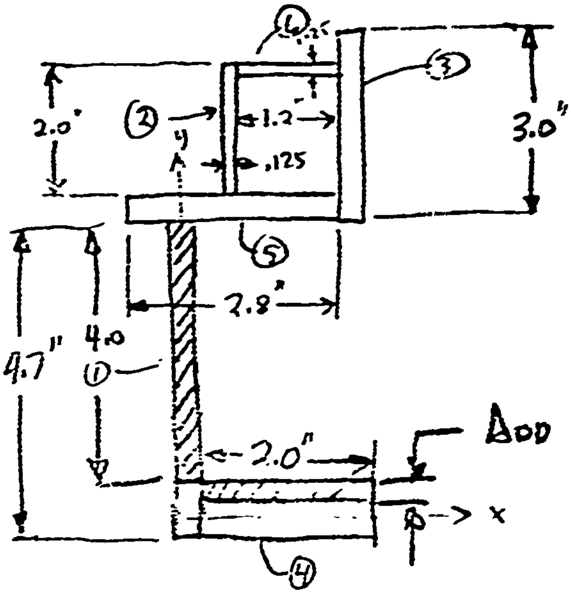
TRICON

RH OR LH UPPER RAIL

ASSUME SAME AS BLIND SIDE UPPER RAIL

$A = 4.24\ IN^2 \quad I_x = 9.45 \quad I_y = 18.57$

RH OR LH LOWER RAIL



ADD t=.25

REVISIONS AT FORKLIFT POCKET

ELEM	A	x	Ax	Ax²	y	Ay	Ay²	Ix	Iy
1	.88	0	0	0	2.30	2.02	4.65	1.65	0
2	.25	.60	.15	.09	5.80	1.45	8.39	.08	0
3	.56	1.95	1.09	2.13	6.05	3.39	20.50	.42	0
4	.37	1.1	.40	.44	0	0	0	0	.13
5	.52	.5	.26	.13	4.70	2.45	11.50	0	.35
6	.15	1.25	.19	.23	6.70	1.00	6.70	0	.02
	2.73		2.09	3.02		10.31	51.74	2.15	.50

$\bar{X} = \frac{2.09}{2.73} = .77''$

$I_y = .50 + 3.02 - 2.73(.77)^2 = 1.92\ IN^4$

$\bar{y} = \frac{10.31}{2.73} = 3.78''$

$I_x = 2.15 + 51.74 - 2.73(3.78)^2 = 15.0\ IN^4$

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TRICON

RH OR LH LOWER RAIL @ FORKLIFT POCKET

CHANGE ELEMENTS ① & ④ FROM PREVIOUS CALCS.

L=.65"

t=.44

ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	Ix	Iy
1	.12	0	0	0	.20	0.02	0	0	0
2	.25	.60	.15	.09	5.80	1.45	8.39	.08	0
3	.56	1.95	1.09	2.13	6.05	3.39	20.50	.42	0
4	.88	1.10	.97	1.06	.10	.09	0	0	.29
5	.52	.50	.26	.13	4.70	2.45	11.50	0	.35
6	.15	1.25	.19	.23	6.70	1.00	6.70	0	.02
	2.48		2.66	3.64		8.40	47.09	.50	.66

$\bar{X} = 1.07''$

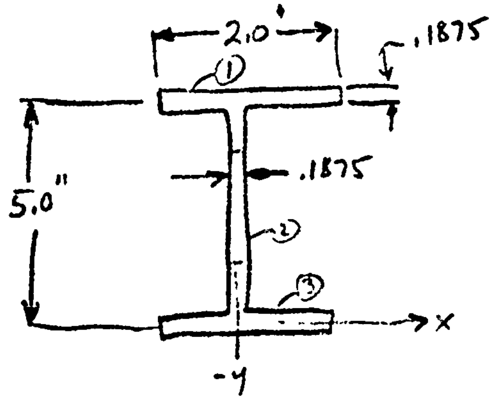
$I_y = \Sigma I_y + Ax^2 - \Sigma A(\bar{x})^2 = .66 + 3.64 - 2.48(1.07)^2 = 1.46 \text{ IN}^4$

$\bar{y} = \dfrac{8.40}{2.48} = 3.39''$

$I_x = \Sigma I_x + Ay^2 - \Sigma A(\bar{y})^2 = .50 + 47.09 - 2.48(3.39)^2 = 19.09 \text{ IN}$

TRICON

FLOOR BEAM



ELEM	A	x	Ax	Ax^2	y	Ay	Ay^2	I_x	I_y
1	.375	0	0	0	5.0	1.875	9.39	0	.12
2	.94	0	0	0	2.5	2.35	5.87	1.98	0
3	.375	0	0	0	0	0	0	0	.12
	1.690					4.225	15.26	1.98	.25

$\bar{y} = \frac{4.225}{1.69} = 2.50$ (REASSURING)

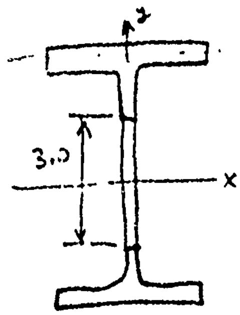
10.55

$I_x = \Sigma I_x + \Sigma A y^2 - \Sigma A(\bar{y})^2 = 1.98 + 15.26 - 1.69(2.50)^2$

$= 6.69 \text{ IN}^4$

$I_y = .254$

FLOOR BEAM @ FORKLIFT POCKET



ELEM	A	I_x	I_y
1	1.69	6.69	.254
2	-.56	-.43	0
	1.13	6.26	.254

TRICON

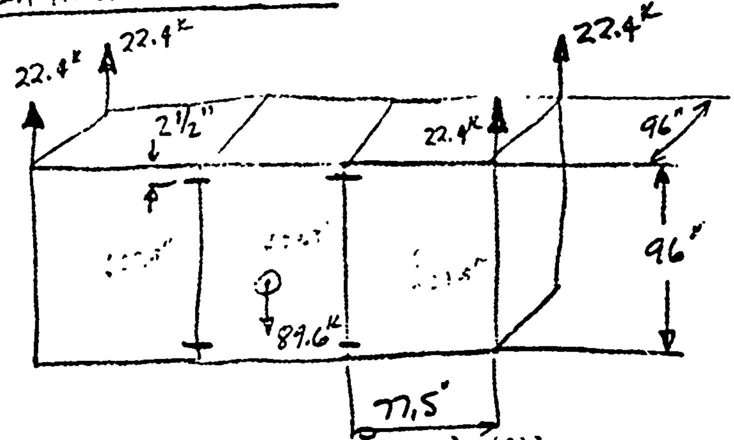
MATERIALS

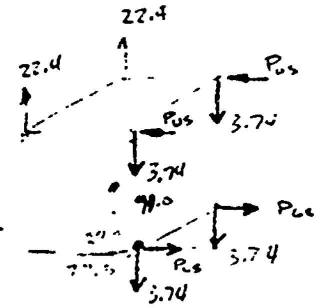
		D2-3617-1			
		A36	A441	4130 125-145 HT TR AFTER WELDING	4130 HT AFFECTED ZONE
	F_{TU} (KSI)	60.	70.0	125.	80.
	F_{TY} "	36.0	50.	103.	63.1
	F_{CY} "	34.2	50.	113.	63.1
	F_{SU} "	36.0	42.	82.	48.9
	$E\ (10)^6$	29.0	29.0	29.0	
WELD	F_{TU}	42.0	42.0	93.7	
"	F_{TY}	33.6	33.6	77.2	
"	F_{SU}	25.2	25.2	56.2	
FILLET "	F_{SU}	25.2	25.2	56.2	

THESE STEELS RUST BADLY AND RAPIDLY. THE MATERIALS PEOPLE SHOULD BE INCLUDED BEFORE THE FINAL MATERIAL SELECTION.

TRICON

LIFTING LOAD - TOP





$$44.8(77.5) - 29.9\left(\frac{77.5}{2}\right) - 2P_{US}(91.0)$$

$$P_{US} = \frac{44.8(77.5) - 29.9(38.7)}{182}$$

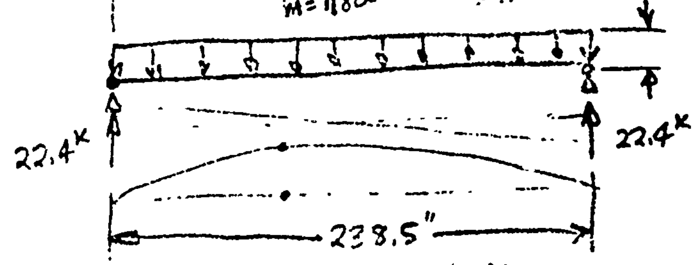
$P_{US} = 12.7^K$

$\frac{M}{d} = \frac{1180}{91} = 13.0^K$

$M = \frac{.188(238.5)}{2}\left(77.5 - \frac{77.5^2}{238.5}\right)$

$M = 1180$

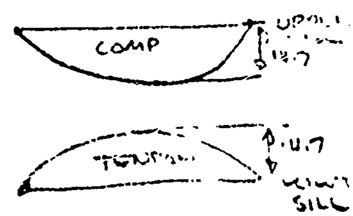
$w = \frac{44.8^K}{2(238.5)_{IN}} = .188\ ^K/_{IN}$ (PER SIDE)



$V_{MAX} = 22.4^K$

$q_{MAX} = \frac{22.4^K}{91.0} = 236\ ^{LB}/_{IN}$ (PER SIDE)

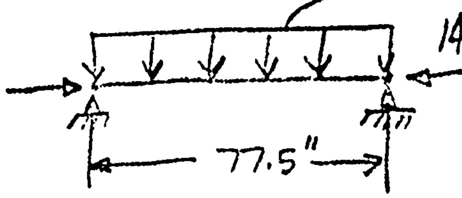
$$M_{MAX} = \frac{wL^2}{8} = \frac{.188(238.5)^2}{8} = 1340\ IN \cdot K$$



$$P = \pm\frac{M}{d} = \frac{1340\ IN\cdot K}{91.0\ IN} = \pm 14.7^K$$

$f = \frac{14.7}{4.02} = 3.66\ ksi$

DOOR UPPER SILL

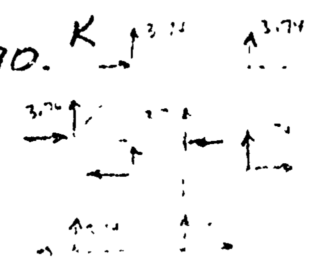


ASSUME SIMPLE SUPPORTS

SEE 9.2

$$P_{CR} = \frac{\pi^2 EI}{L^2} = \frac{9.86(29.0)(10)^3(14.5)}{(77.5)^2} = 690.^K$$

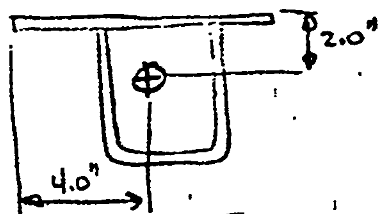
$$f_{CR} = \frac{690}{4.02} = 172.0\ ksi$$



TRICON

LIFTING LOAD-TOP

ASSUME NO VERTICAL ECCENTRICITY AND 4.0" FORE AND AFT ECCEN



$$f_{max} = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{P}{AE}}\right)\right]$$

$c = 4.0"$ $e = 4.0"$ $r = \left(\frac{I}{A}\right)^{1/2} = \left(\frac{14.5}{4.02}\right)^{1/2} = 1.9 \text{ IN}^2$ (3.61)

$$\sqrt{\frac{P}{AE}} = \left(\frac{14.7}{4.02(29.0)10^3}\right)^{1/2} = \left(1.26(10)^{-4}\right)^{1/2} = .0112$$

$$\frac{L}{2r} = \frac{77.5}{2(1.9)} = 20.4 \qquad \frac{L}{2r}\sqrt{\frac{P}{AE}} = .228 \text{ rad} = 13.1^\circ$$

$\sec 13.1^\circ = 1.027$

$$\frac{ec}{r^2}(1.027) = \frac{4.0(4.0)(1.027)}{3.61} = 4.55$$

$$f_{MAX} = \frac{14.7}{4.02}\left[1 + 4.55\right] = 20.3 \text{ KSI}$$

$$M_{MAX} = \frac{wl^2}{8} = \frac{52.0(77.5)^2}{8} = 39.0 \text{ IN-K}$$

$$f_b = \frac{39.0(3.5)}{18.7} = 7.3 \text{ KSI}$$

$f_{TOTAL} = 20.3 + 7.3 = 27.6$ KSI

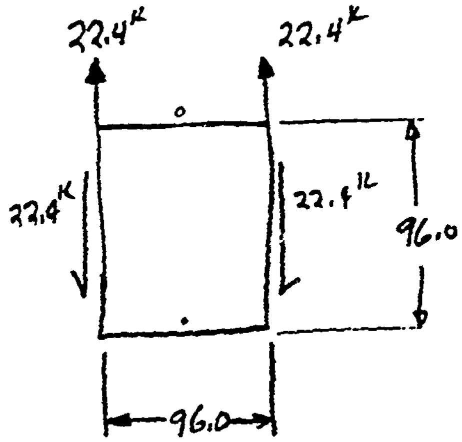
CAN USE $F_{TY} = 36.0$ KSI

JST 4-28-71

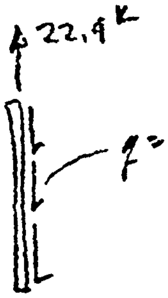
TRICON

LIFTING LOAD - TOP

UPPER SIDE RAIL



DOOR POST & BLIND SIDE POST



$$q = \frac{22.4}{91.0} = 236.0 \text{ LB/IN}$$

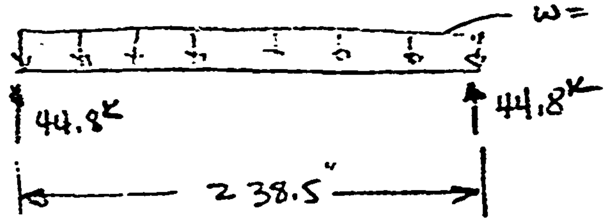
BLIND SIDE TOP RAIL

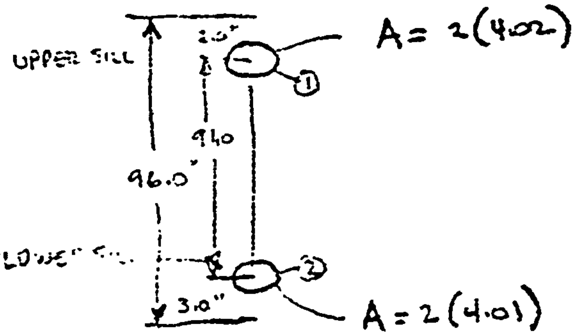
TRICON

LIFTING LOAD - TOP

CHECK VERTICAL DEFLECTION (LIMIT 1/4" @ ℄)

$w = \frac{89.6}{238.5} = 366$ LB/IN





ELEM	A	x	Ax	Ax²	Iy
1	8.04	91.0	731	66500	19.0
2	8.02	0	0	0	19.0
	16.06		731	66500	38.0

$\bar{x} = \frac{731}{16.06} = 45.5''$

$I = 6650 + 38 - 16.06(45.5)^2 = 33{,}300$

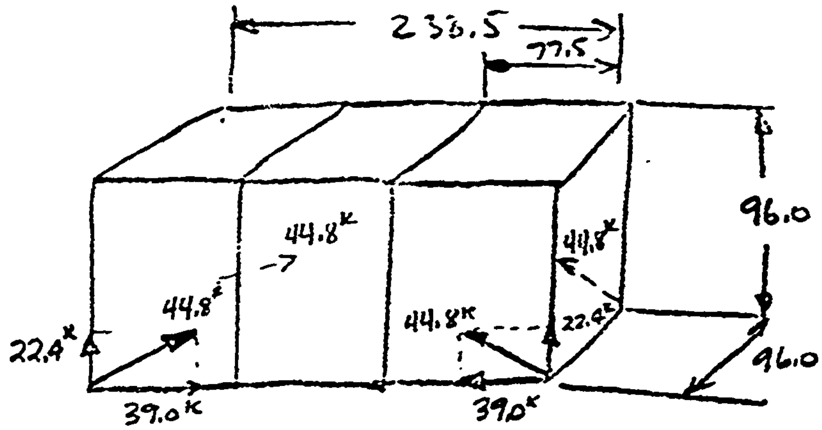
$$\delta_{max} = \frac{5}{384}\left(\frac{wl^4}{EI}\right) = \frac{5(.366)(238.5)^4}{384(29)(10)^3(33.3)(10)^3} = \frac{59.5(10)^8}{3710(10)^8}$$

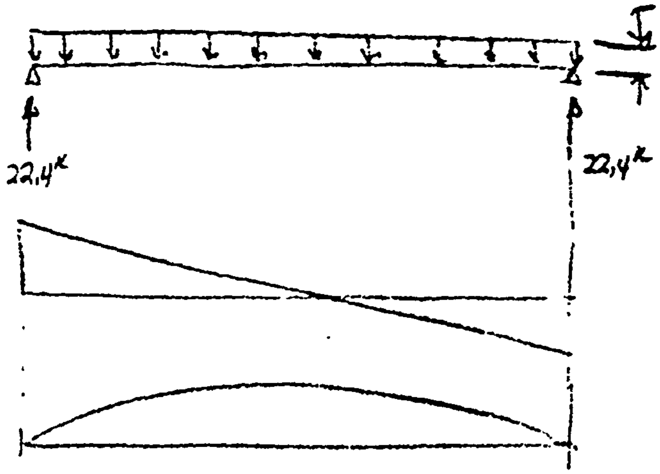
$\delta_{MAX} = .016''$

THE GAPS BETWEEN THE LATCHES CONNECTING THE TRICONS WILL PROBABLY GIVE MORE DEFLECTION THAN THIS.

TRICON

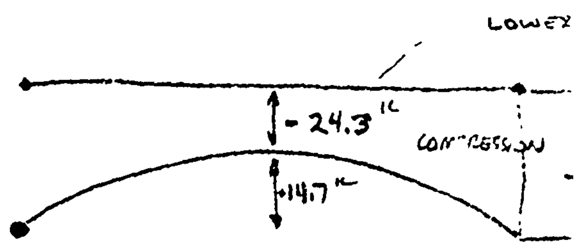
LIFTING LOAD - BOTTOM

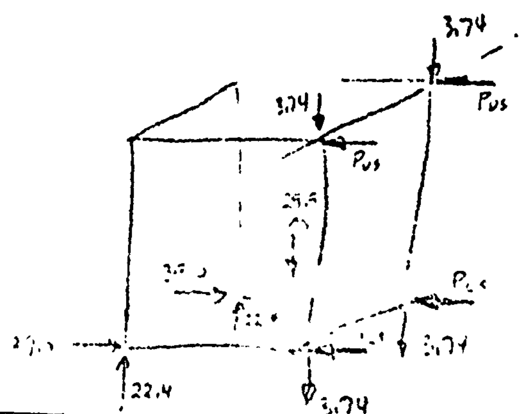




$w = \frac{44.8}{238.5} = .188\ {}^{K}/_{IN}$ (PER SIDE)

$q_{MAX}: \frac{22.4}{96.0} = .236\ {}^{K}/_{IN}$





$44.8(77.5) \overset{?}{=} (39.0)(96.0) - 29.9\left(\frac{77.5}{2}\right) + 2(P_{LS})(96.0)$

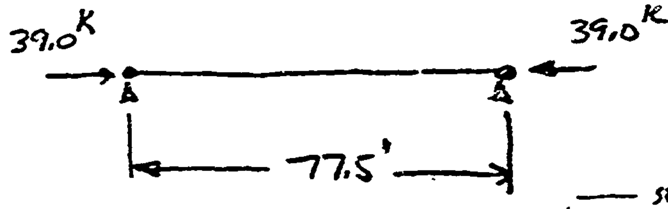
$P_{LS} = \frac{7480 + 1160 - 3470}{192} = 27.0^{K}$

JUT 4-28-71

TRICON

LIFTING LOAD - BOTTOM

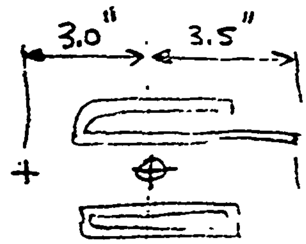
LOWER DOOR SILL



SEE P. ①

$$P_{CR} = \frac{\pi^2 E I}{L^2} = \frac{9.86(29)(10)^3(9.0)}{(77.5)^2} = 428^K$$

$$f_{CR} = \frac{428^K}{4.01} = 117 \text{ KSI}$$



$$P = 39.0^K$$

$$f = \frac{39.0}{4.01} = 9.73 \text{ KSI}$$

ASSUME NO VERTICAL ECCENTRICITY AND 3.0" FORE-AND-AFT ECCEN

$$f_{MAX} = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{L}{2r}\sqrt{\frac{P}{AE}}\right)\right]$$

$$c = 3.5" \quad r = \sqrt{\frac{I}{A}} = \left(\frac{9.0}{4.01}\right)^{1/2} = 1.497 \text{ USE } 1.5$$

$$\sqrt{\frac{P}{AE}} = \left[\frac{39.0}{4.01(29.0)10^3}\right]^{1/2} = \left(3.35(10)^{-4}\right)^{1/2} = .0183$$

$$\frac{L}{2r} = \frac{77.5}{2(1.5)} = 25.8 \quad \therefore \frac{L}{2r}\sqrt{\frac{P}{AE}} = .473 \text{ RAD} = 27.1^\circ$$

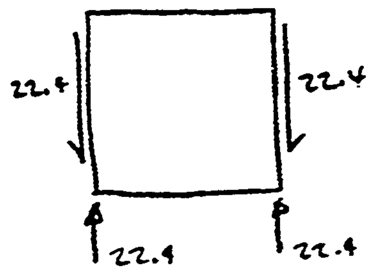
$$\sec 27.1^\circ = 1.123 \quad \therefore \frac{ec}{r^2}(1.123) = \frac{3.0(3.5)}{2.25}(1.123) = 5.25$$

$$f_{MAX} = \frac{39.0}{4.01}\left[1 + 5.25\right] = 60.6 \text{ KSI}$$ ← CANNOT EXCEED $\frac{f_y}{n}$

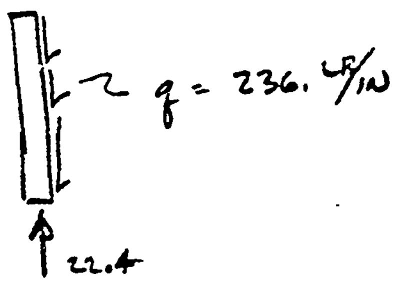
TRICON

LIFTING LOAD – BOTTOM

UPPER SIDE RAIL



DOOR POST & BLIND SIDE POST

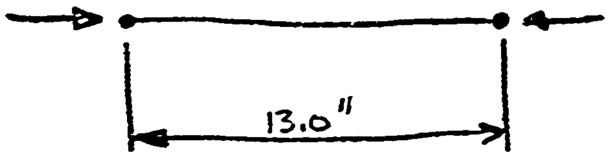


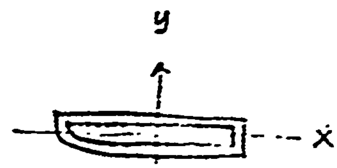
TRICON

LIFTING LOAD - BOTTOM

LOWER DOOR SILL

CHECK UNSUPPORTED LOWER MEMBER AT FORK LIFT CUTOUT





$A = 1.84$ IN

$I_x = .27$ IN^4

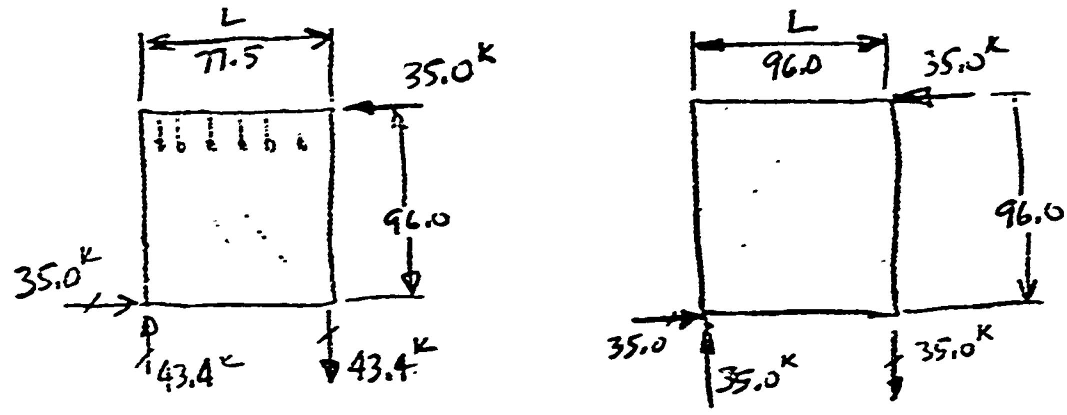
ASSUME $f = 9.73$ KSI (SEE P. 13) $\therefore$ $P = 9.73(1.84) = 17.9$

$$P_{CR} = \frac{\pi^2 E I}{\ell^2} = \frac{9.86(29)(10)^3(.27)}{\underset{169}{(13)(13)}} = \frac{77.3(10)^3}{169} = 456.^K$$

NOT CRITICAL

TRICON

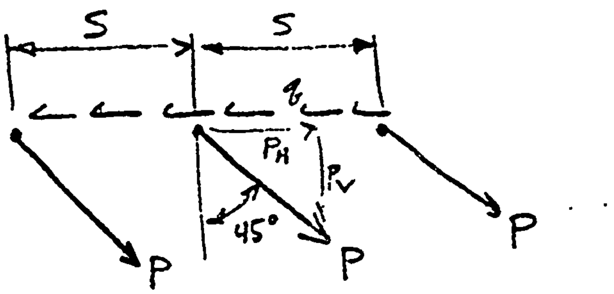
RACKING – STRAP LOADS



MAXIMUM SHEAR FLOW OCCURS ON BLIND SIDE, $q = \frac{P}{L}$

$$q_1 = \frac{35.0}{70.0} = 500.\ \text{LB/IN}$$

$$q_2 = \frac{35.0}{90.0} = 389\ \text{LB/IN}$$



72.3

$P_H = P_V = q\,S$

ASSUME $S = 5.0''$

$P_H = P_V = 500(5.0) = 2500^{\#}$ (MAX)

$P'_H = P'_V = 389(5.0) = 1945^{\#}$

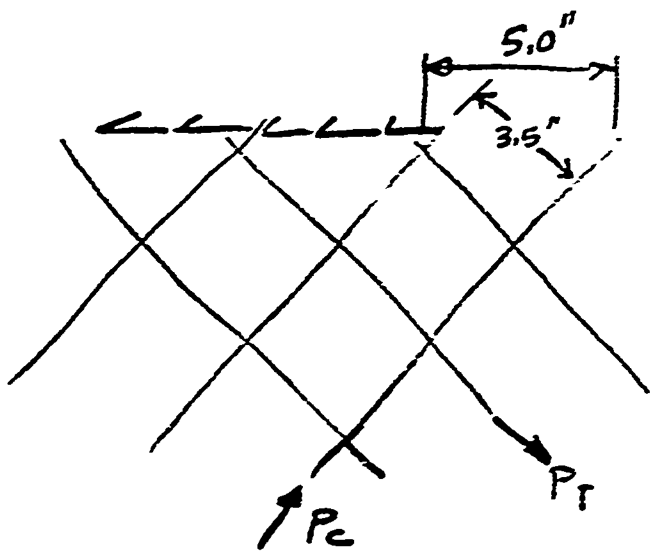
STRAP LOAD $= \frac{P_H}{.707} = 1.414\,P_H = 3540^{\#} = P$

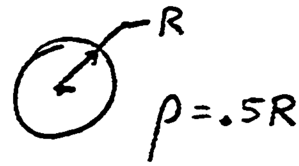
$P' = 2750^{\#}$

TRICON

RACKING LOAD

CHECK STRAP EFFECTIVETY IN COMPRESSION





FOR 1/4" @ 5.0" $\rho = .5\left(\frac{.25}{2}\right) = .0625$

$L = 3.5 \qquad \frac{L}{\rho} = \frac{3.5}{.0625} = 56.0$

FOR 4130 $F_{cy} \approx 67.5^{KSI} \qquad F_{TY} = 75.0$ KSI

$F_{CR} = 60.0$ KSI FOR $\frac{L}{\rho} = 56.0$

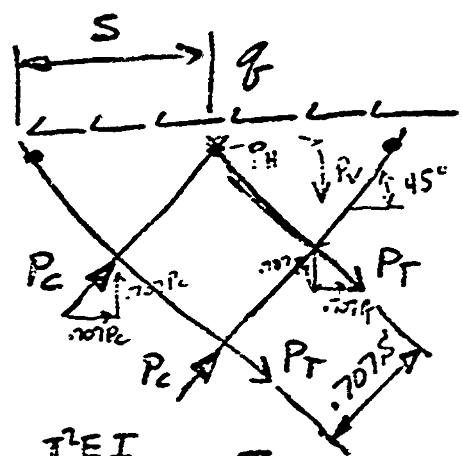
∴ IT APPEARS THAT STABILIZING THE RODS FOR PINNED ENDS AT THE INTERSECTION IS WORTHWHILE.

JOT 5-5-?

TRICON

RACKING LOADS

STRAP EFFECTIVETY



ASSUME MAXIMUM ... CARRIED BY STRAPS ONLY.

$$q = \frac{35.0}{77.5 - 14.0} = 550$$

D	D^2	D^4
3/16	.0352	.001
1/4	.0625	.003

$$P_C = P_{CR} = \frac{\pi^2 EI}{(.707S)^2} = \frac{\pi^2 EI}{.5S^2} = < F_{CY}$$

$$A = \frac{\pi D^2}{4}$$

$$P_T = F_{TY} A$$

$$I = \frac{\pi D^4}{64}$$

$$P_H = P_C(.707) + P_T(.707) = .707(P_C + P_T)$$

$$P_V = P_T(.707) - P_C(.707) = .707(P_T - P_C)$$

$$P_H = qS = .707\left[\frac{\pi^2 EI}{.5S^2} + F_{TY}A\right] = .707\left[\frac{\pi^2 E \pi D^4}{.5(64)S^2} + \frac{F_{TY}(\pi D^2)}{4}\right]$$

$$qS = .707\left[\frac{\pi^3 E D^4}{32\,S^2} + \frac{\pi F_{TY} D^2}{4}\right] = .707\left[28.1(10)^6\left(\frac{D^4}{S^2}\right) + 59.0(10)^3 D^2\right]$$

$$(550)S - 19.9(10)^6\left(\frac{D^4}{S^2}\right) - 41.6(10)^3 D^2 = 0$$

MULTIPLY BOTH SIDES BY

$$550(S)^3 - 41.6(10)^3 D^2 (S)^2 = 19.6(10)^6 D^4$$

JOT 5-5-71

TRICON

RACKING LOADS

STRAP EFFECTIVETY

TRY $D = .25$ $D^2 = 62.5(10)^{-3}$ $D^4 = 3910(10)^{-6}$

$$550\,S^3 - 41.6(62.5)S^2 - 19.6(3910) = 0$$

$$550\,S^3 - 2600\,S^2 - 74600 = 0$$

$$a = \frac{1}{3}(3q - p^2) \qquad q = 0 \quad a = -\frac{p^2}{3} \quad y = x - \frac{p}{3}$$

$$b = \frac{1}{27}(2p^3 - 9pq + 27r) = \frac{1}{27}(2p^3 + 27r) = \frac{2}{27}p^3 + r$$

$$S^3 \underbrace{- 4.73}_{p} S^2 \underbrace{- 139}_{r} = 0$$

$$A = \sqrt[3]{-\frac{b}{2} + \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}}$$

FOR $p = -4.73$ $r = -139$ $a = -\frac{\overset{+22.4}{(-4.73)^2}}{3} = -7.45$ ✓

$$b = \frac{2}{27}\overset{-105.5}{(-4.73)^3} - 139 = -7.8 - 139. = -147$$

$$\left(\frac{\overset{21600}{b^2}}{4} + \frac{a^3}{27}\right) = 5400 + (-15.3) = 5385 > 0$$ ONE REAL ROOT TWO CONJUGATE IMAGIN.

$$(5385)^{1/2} = 73.3$$

$$A = \left(-\frac{\overset{73.5}{-147}}{2} + 73.3\right)^{1/3} = 5.30$$ 146.8

$$B = \sqrt[3]{-\frac{b}{2} - \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}} = (73.5 - 73.3)^{1/3} = 0$$

$X_1 = A + B = 5.30$ (REAL ROOT)

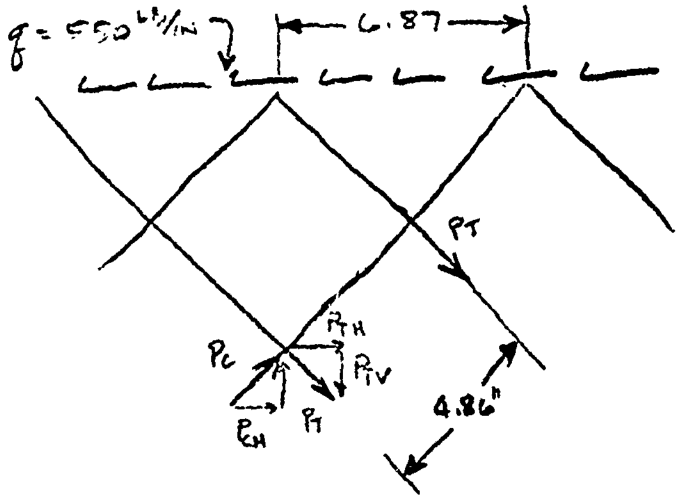
$$y = X - \frac{p}{3} = 5.30 - \frac{\overset{1.57}{-4.73}}{3} = 5.30 + 1.57 = 6.87'' = S$$

TRICON

RACKING LOAD

STRAP EFFECTIVITY

CHECK LOADS & STRESSES IN 1/4" ROD @ 6.87"



1/4" ROD

A = .049

I = .000192

$\frac{3.14(.0039.)}{64}$

.000192

$$P_C = P_{CR} = \frac{\pi^2 E I}{\ell^2} = \frac{9.86(29.0)(10)^6(192)(10)^{-6}}{(4.86)^2} = \frac{54900}{23.7} = 2320^{\#}$$

23.7

$$P_{CH} = .707\, P_C = 1640^{\#} = P_{CV} \qquad f_c = \frac{2320}{.049} = -47.4\text{ K}$$

3780

$$P_{TH} = qS - P_{CH} = 550(6.87) - 1640 = 2140^{\#} = P_{TV}$$

$$P_T = \frac{P_{TH}}{.707} = 3030^{\#}$$

$$f_T = \frac{3030}{.049} = 61.8 \text{ KSI}$$

SUMMATION OF VERTICAL LOADS = $P_{TV} - P_{CV} = 2140 - 1640 = 500$

$$w = \frac{500^{\#}}{6.87"} = 73\ ^{\#}/\text{IN}$$

JOT

TRICON

RACKING LOAD

STRAP EFFECTIVETY

TRY $D = .1875$ $D^2 = 35.2(10)^{-3}$ $D^4 = 1235(10)^{-6}$

$550\,\delta^3 - 41.6(35.2)\delta^2 - 19.6(1235) = 0$

$\delta^3 \underbrace{- 2.68}_{p}\delta^2 \underbrace{- 44}_{r} = 0$

$a = -\frac{p^2}{3} = -\frac{(-2.68)^2}{3} = \frac{-(7.19)}{3} = -2.40$

$b = \frac{2}{27}p^3 + r = \frac{2}{27}(-2.68)^3 - 44 = -1.4 - 44.0 = -45.4$

$\left(\frac{b^2}{4} + \frac{a^3}{27}\right) = \frac{(-45.4)^2}{4} + \frac{(-2.40)^3}{27} = 515 - .5 = 514.5$

$\left(\frac{b^2}{4} + \frac{a^3}{27}\right)^{1/2} = (514.5)^{1/2} = 22.7$

$A = \sqrt[3]{-\frac{b}{2} + \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}} = \left[-\frac{(-45.4)}{2} + 22.7\right]^{1/3} = [45.3]^{1/3} = 3.57$

$B = \sqrt[3]{-\frac{b}{2} - \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}} = \left[-\frac{(-45.4)}{2} - 22.7\right]^{1/3} = 0$

$X = A + B = 3.57$

$y = \delta = X - \frac{p}{3} = 3.57 - \frac{(-2.68)}{3} = 3.57 + .89 = 4.46''$

CHECK LOADS & STRESSES IN 3/16"

$g(\delta) = 550(4.46) = 2460^{\#} = P_H$

$P_{CR} = \frac{\pi^2 EI}{[.707(4.46)]^2} = \frac{9.86(29.0)(10)^6(\pi)(1235)(10)^{-6}}{64(10)} = \frac{1.11(10)^6}{.64(10)^{+3}} = 1,730^{\#}$

$P_{CH} = .707(1730) = 1225^{\#}$ $\therefore P_{T_H} = P_H - P_{CH} = 2460 - 1225 = 1235^{\#}$

$\therefore P_T = \frac{1235}{.707} = 1750^{\#}$ $f_T = \frac{1750}{.0276} = 63.6$ KSI

TRICON

RACKING LOAD

STRAP EFFECTIVETY

IF IT IS DESIRED TO KEEP THE OUT-OF-PLANE LOAD ON THE EDGE MEMBERS TO A MINIMUM, THE TENSION LOAD SHOULD EQUAL THE COMPRESSION LOAD.

OR $P_H = .707(P_c + P_c) = 1.414\,P_c$ ← ASSUMES STABILITY CRITICAL. IF TENSION CRITICAL WOULD USE AREA FUNCTION HERE.

$$\therefore\ q\,S = 1.414\left(\frac{\pi^2 EI}{.5\,S^2}\right) = 1.414\left(\frac{\pi^3 E D^4}{32\,S^2}\right)$$

$$q\,S = 1.414\,(28.1)(10)^6\,\frac{D^4}{S^2} = 39.8(10)^6\left(\frac{D^4}{S^2}\right)$$

OR

$$(550)\,S^3 = 39.8(10)^6\,D^4$$

$$S = \left[7.24(10)^4 (D)^4\right]^{1/3}$$

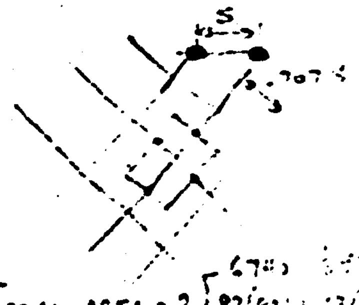
FOR $\frac{1}{4}$" RODS $(D)^4 = .00391 = 39.1(10)^{-4}$ (6.21)

$$S = \left[\overset{283}{7.24(39.1)}\right]^{1/3} = 6.59\text{"} \quad \left(\tfrac{1}{4}\text{" RODS}\right)$$

FOR $\frac{3}{16}$" RODS $(D)^4 = 12.35(10)^{-4}$ (3.55)

$$S = \left[\overset{89.4}{7.24(12.35)}\right]^{1/3} = 4.46\text{"} \quad \left(\tfrac{3}{16}\text{" RODS}\right)$$

$S = 2.61$" ($\frac{1}{8}$" RODS)



WEIGHTS

AREA $= (.707\,S)^2 = .5\,S^2$

LENGTH $= 1.414\,S$

VOLUME = LENGTH (AREA)

$$\bar{t} = \frac{\text{VOLUME}}{\text{AREA}} = \frac{1.414\,S\,(\text{AREA})}{.5\,S^2} = \frac{2.828\,(\text{AREA})}{S}$$

$\bar{t}_{1/4} = \frac{2.83(.049)}{6.59} = \cancel{.0214}\ .0214$ } $\Delta t = .0036$

$\bar{t}_{3/16} = \frac{2.83(.0276)}{4.46} = \cancel{.0175}\ .0178$ }

TOTAL AREA = 2 [82(...) + ...(...)] = ...

~~...~~ WEIGHT = %

ΔW = 217 # (...%...)

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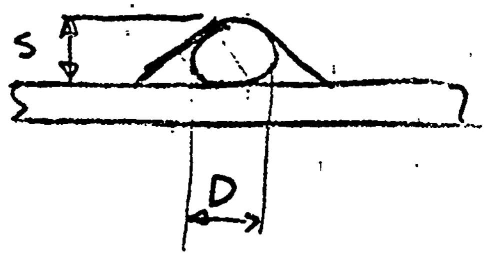
JOT 5-5-71

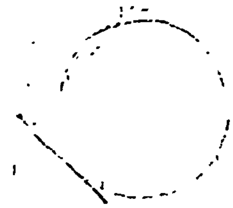
TRICON

RACKING LOAD

STRAP EFFECTIVETY

WELD LENGTH





MIL-5

8.2.2.1

(Use 85% BA

$S = D$ Assume $W_{eff} = .707D$ $A_{TOTAL} = 2(.707)D\,L$

Assume $P_{ULT} = F_{TU} \cdot A_{ROD}$ $F_{SU} = \frac{P_{ULT}}{A_{TOTAL}} = \frac{F_{TU}\,A_{ROD}}{1.414\,D\,L}$

Assume 4130 125 KSI H.T. OR $L = \frac{F_{TU}}{F_{SU}}\left(\frac{A_{ROD}}{D_{ROD}}\right)\left(\frac{1}{1.414}\right)$

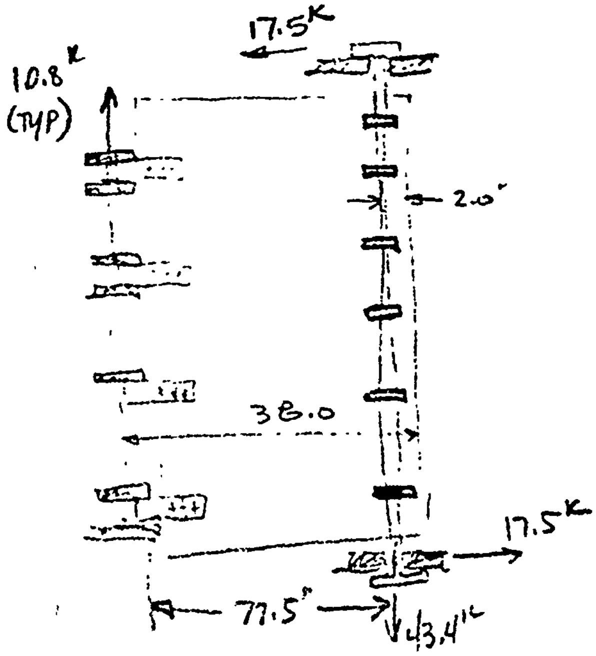
$F_{SU} = 63.0$ KSI (TABLE 8.2.1.1.1) $L = \frac{F_{TU}}{F_{SU}}(.555$

D		A	FTU	PULT	L
3/16	.188	.0276	105.0	2.90K	.173"
1/4	.250	.049	105.0	5.15K	.23"

TRICON

RACKING LOAD

DOORS

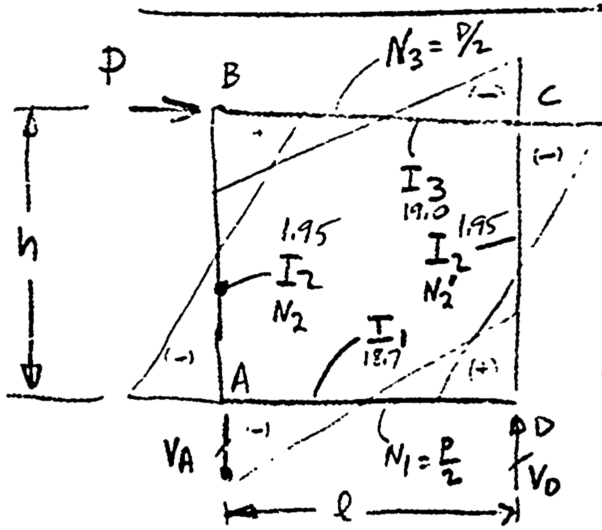


$$\text{ASSUME}\quad q_1 = \frac{17.5}{36.0} = 486\ \text{LB/IN},\qquad q_2 = \frac{43.4}{93.0} = 466\ \text{LB/IN}\quad\Big\}\ \text{USE } q_{DOOR} = 500\ \text{LB/IN}$$

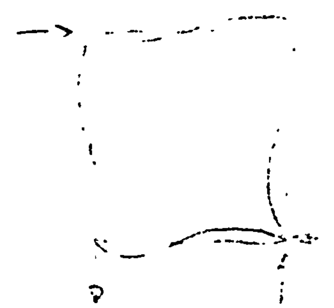
DOOR NOT DESIGNED — CAN'T ANALYZE

TRICON

RACKING LOAD – NO DOOR – RIGID FRAME REACTION



KLEINLOGEL FRAME 106 P. 394



$$M_B = -M_C = +\frac{P h R_2}{2F_2}$$

$$M_D = -M_A = +\frac{P h R_1}{2F_2}$$

$$N_2' = -N_2 = \frac{2M_B}{l}$$

$$R_2 = k_1 + 3k_2 \qquad F_2 = 1 + k_1 + 6k_2$$

$$R_1 = 3k_2 + 1 \qquad k_1 = \frac{I_3}{I_1} \quad k_2 = \frac{I_3}{I_2}\left(\frac{h}{l}\right)$$

$$k_1 = \frac{18.7}{19.0} = .984$$

$$k_2 = \frac{19.0}{1.95}\left(\frac{96.0}{77.5}\right) = 12.1$$

$$F_2 = 1.0 + .984 + 6(12.1) = 74.5$$

72.5

36.3

$$R_2 = .984 + 3(12.1) = 37.3$$

$$R_1 = 3(12.1) + 1.0 = 37.3$$

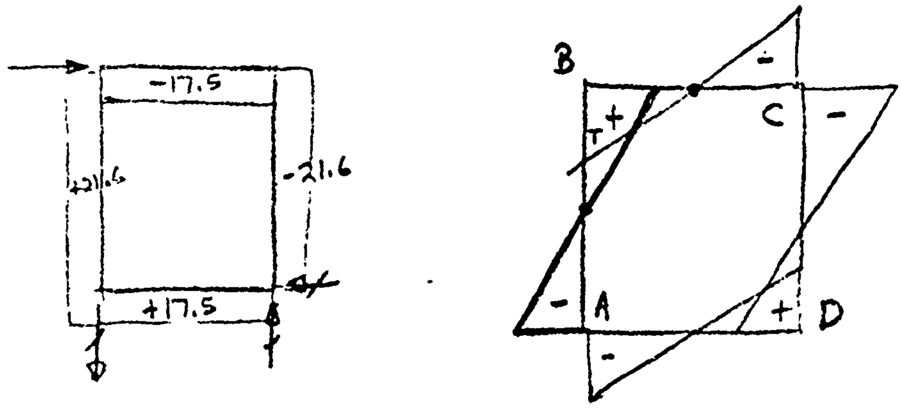
TRICON

RACKING LOAD – NO DOOR – RIGID FRAME DISTRIBUTION

$$M_B = -M_C = \frac{PhR_2}{2F_2} = \frac{35.0(96.0)(37.3)}{2(74.5)} = 841.\ \text{IN}\cdot\text{K}$$

$$M_D = -M_A = \frac{PhR_1}{2F_2} = 841.\ \text{IN}\cdot\text{K}$$

$$N_2' = -N_2 = \frac{2(841)}{77.5} = 21.7^K$$



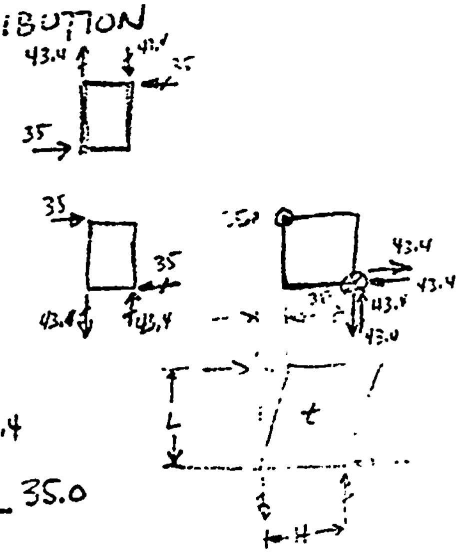
FRAME STIFFNESS ALONE IS NOT A VERY EFFICIENT METHOD OF DISTRIBUTING THE RACKING LOAD ON THE DOOR SIDE. NEED

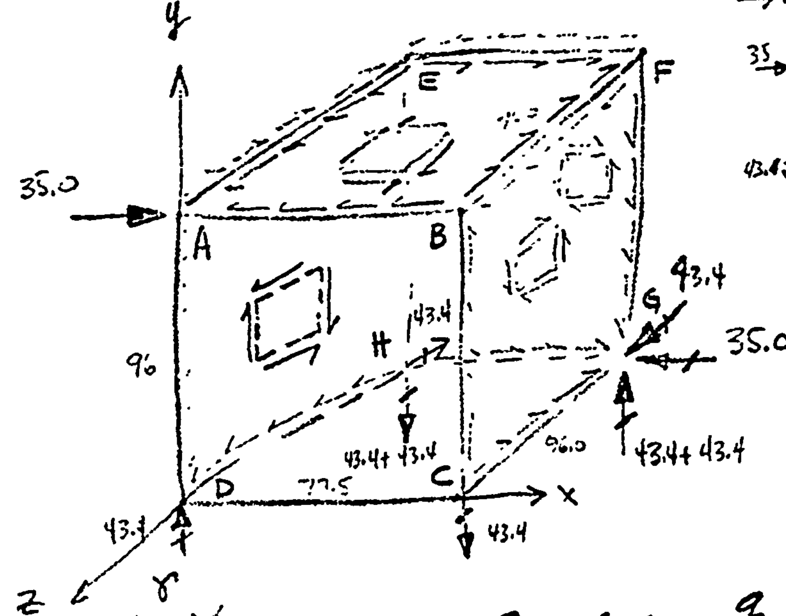
1) STRUCTURAL DOOR AND/OR
2) SHEAR DISTRIBUTION THRU ROOF, ETC.

TRICON

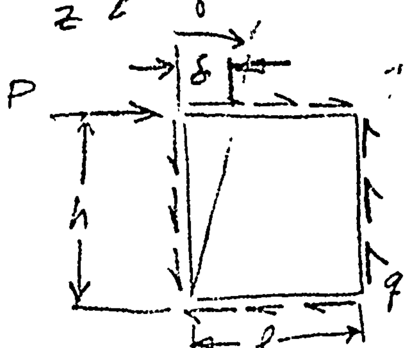
RACKING – DOOR SIDE – SHEAR PANEL DISTRIBUTION

CHECK SHEAR PANEL LOAD DISTRIBUTION





$\delta = \frac{PL}{HtG}$



$\tau = G\gamma = \frac{q}{t}$

$\gamma = \frac{q}{Gt}$

FOR SMALL ANGLES $\tan\gamma = \gamma$

$\tan\gamma = \frac{\delta}{h}$ $\therefore$ $\delta = \tan\gamma\,(h) = \frac{qh}{Gt}$

ASSUME $\frac{1}{4}$" RODS @ 5.0" SPACING ON HEADERS ($\alpha = \pm 45°$)

EQUIVALENT TO 3.5" ON CENTER

ASSUME ONLY RODS IN TENSION ARE ACTING

$A_{ROD} = .049$ $L_{ROD} = 3.5"$

$V_{ROD} = 3.5(.049) = .172\ IN^2$

$\bar{t} = \frac{.172}{12.5} = .014$

NOTE: FOR $\frac{1}{4}$" RODS @ 6.87", THE COMPRESSION R... ARE OPERATING AT $\frac{47.4}{61.6} = .765$ OF THE TOTAL RODS. THIS RESULTS IN THE FOLLOWING $\bar{t}$.

$\bar{t} = \frac{4.86(.049) + 4.86(.049)(.765)}{23.7} = .0177$

TRICON

RACKING - DOOR SIDE

LOWER SIDE RAIL

ASSUME $P = 43.4 - 23.4(.45) = 33.0^{K}$

$f_{AXIAL} = \dfrac{33.0}{2.73} = 12.1$ KSI

$P_{\substack{LOWER\\CHORD}} = 12.1\,(.924) = 11.2$ KIPS

$P_{WEB} = 12.1\,(4.2)(.1875) = 9.54^{K}$

ASSUME OUTER CHORD CARRIES HALF

$P'_{LC} = .5(9.54) = 4.77^{K}$

$P_T = 11.2 + 4.8 = 16.0^{K}$

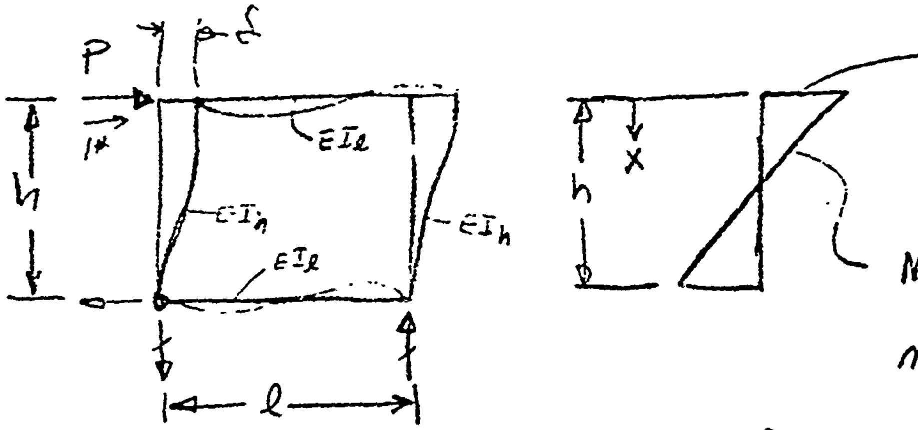
$f = \dfrac{16.0^{K}}{.924} = 17.4$ KSI

$M.S. = \dfrac{27.5}{17.4} - 1 = +.58$

THIS CHORD IS SUBJECT TO HANDLING DAMAGE AND THE OPERATING CRITERIA SHOULD BE REVIEWED WITH THIS IN MIND.

TRICON

RACKING LOAD - DOOR SIDE - RIGID FRAME DIST.



$$M = \frac{Ph}{2}\left(\frac{R_2}{F_2}\right)$$

$$m = \frac{h}{2}\left(\frac{R_2}{F_2}\right)$$

$$M_x = M\left(1 - \frac{2x}{h}\right)$$

$$m_x = m\left(1 - \frac{2x}{h}\right)$$

$$\delta_h = \int_0^h \frac{Mm\,dx}{EI} = \int_0^h \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2\left(1-\frac{2x}{h}\right)^2 dx}{EI}$$

$$= \int_0^h \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2 dx}{EI_h} - \int_0^h \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2\left(\frac{4x}{h}\right)dx}{EI_h} + \int_0^h \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2\left(\frac{4x^2}{h^2}\right)}{EI_h}$$

$$= \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2 h}{EI_h} - \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2 4\left(\frac{h^2}{h}\right)}{2EI_h} + \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2(4)\left(\frac{h^3}{h^2}\right)}{3\,EI_h}$$

$$= \frac{P\left(\frac{h}{2}\right)^2\left(\frac{R_2}{F_2}\right)^2}{EI_h}\left[h - 2h + \overset{.333h}{\frac{4h}{3}}\right] \quad \frac{h}{3}$$

$$= \frac{35.\left(\frac{96}{2}\right)^2\left(\frac{37.3}{74.5}\right)^2}{29(10)^3(1.95)}\left[\frac{96}{3}\right] = \frac{35(2300)(.25)(96)}{29(1.95)(3)(\cancel{10^3})} = \frac{1930}{1.70} = 1.$$

$$\delta_l = \delta_H\left[\frac{\left(\frac{l}{2}\right)^2 I_h\left(\frac{l}{3}\right)}{\left(\frac{h}{2}\right)^2 I_l\left(\frac{h}{3}\right)}\right] = 11.35\left[\frac{(1500)(1.95)(26.8)}{(2300)(18.7)(32.0)}\right] = .645''$$

$$\delta_{TOT} = 2\delta_H + 2\delta_l = 2(11.35) + 2(.645) = 24.0\,''$$

$$K_{RF} = \frac{P}{\delta} = \frac{35000}{24.0} = 1460\ \#/in$$

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TRICON

ROCKING LOAD – DOOR SIDE

$K_{TOTAL} = K_{SP} + K_{RF} = 28.0 + 1.5 = 29.5\ ^{K}/_{IN}$

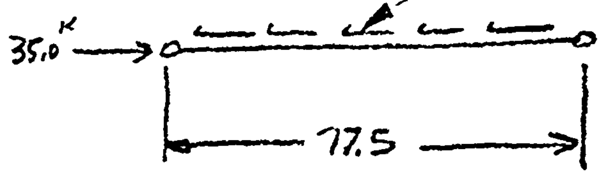
$$\left.\begin{aligned} P_{SP} &= 35.0\left(\frac{28.0}{29.5}\right) = 33.2^{K} \\ P_{RF} &= 35.0\left(\frac{1.5}{29.5}\right) = 1.8^{K} \end{aligned}\right\} P_{TOTAL} = 35.0^{K}$$

ROOF/SIDEWALL STIFFNESS IS ADEQUATE TO TAKE THE RACKING LOAD ON THE DOOR SIDE.

TRICON

RACKING – DOOR SIDE

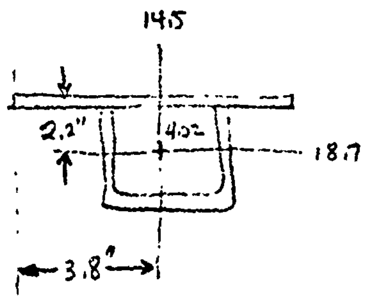
DOOR UPPER SILL



$$\ell_{eff} = .732(\ell) = 56.8''$$

$$\frac{\ell}{\rho} = \frac{56.8}{1.9} = 29.9 \qquad F_{CR} = \frac{\pi^2 E}{\left(\frac{\ell}{\rho}\right)^2} = \frac{9.86\,(29)(10)^3}{(29.9)^2} = 320$$

$$F_{CR} = F_{CY}$$



$$\rho = \left(\frac{14.5}{4.02}\right)^{1/2} = 1.9$$

Assume $e = 2.0''$

$$M = 2(35.0) = 70.0 \text{ IN-K}$$

$$f_b = \frac{70.0(3.8)}{(14.5)} = 18.3$$

$$f_A = \frac{35.0}{4.02} = 8.7$$

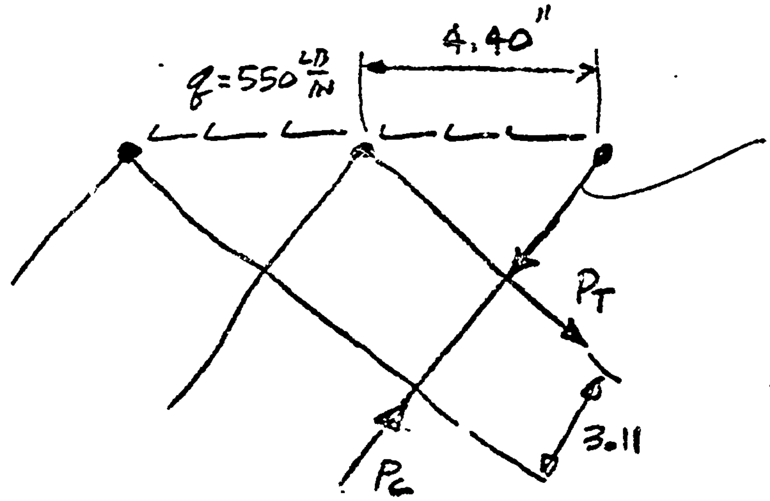
$$f = 27.0 \text{ KSI}$$

CAN USE $F_{TY} = 30.0$ KSI STEEL

TRICON

RACKING - DOOR SIDE

SIDE WALL



$\frac{3}{16}$" ϕ

$D^4 = 1235(10)^{-6}$

$\rho = \frac{R}{2} = \frac{.1875}{4} = .0469$

$A = .0276$

$$P_C(.707) + P_T(.707) = q\,S$$

$$1.414\,P_C = q\,S \quad \therefore \quad P_C = \frac{550(4.4)}{1.414} = 1.71^K$$

$$f_{CR} = \frac{\pi^2 E}{\left(\frac{L}{\rho}\right)^2} = \frac{9.86(29)(10)^6}{\left(\frac{3.11}{.0469}\right)^2} = \frac{286(10)^6}{4410} = 64.6 \text{ KSI}$$

$$f = \frac{1.71^K}{.0276} = 62.0 \text{ KSI}$$

$$M.S._{BUCKLING} = \frac{64.6}{62.0} - 1 = \underline{\underline{+.04}}$$

Assume $F_{TY} = 75.0$ ksi

$$MS_{YIELD} = \frac{75.0}{62.0} - 1 = \underline{\underline{+.21}}$$

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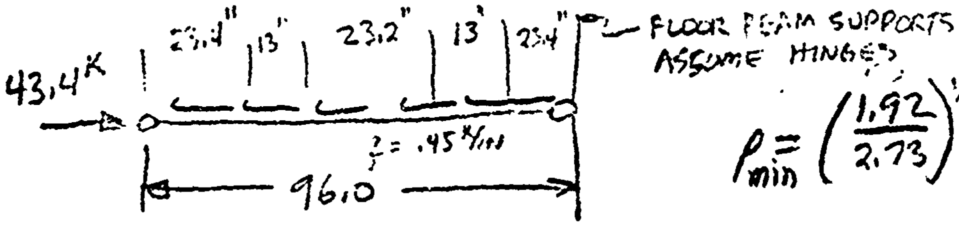
TRICON

RACKING – DOOR SIDE

LOWER SIDE RAIL



$$\rho_{min} = \left(\frac{1.92}{2.73}\right)^{1/2} = .876$$

$$f_{CR} = \frac{\pi^2 E}{\left(\frac{L}{\rho}\right)^2} = \frac{9.86(29)(10)^6}{\left(\frac{23.4}{.876}\right)^2} = \frac{286(10)^6}{712} = 400{,}000 \text{ psi}$$

26.7

Assume $e = 2.0"$ $\quad M = 2(43.4) = 86.8$ IN·K

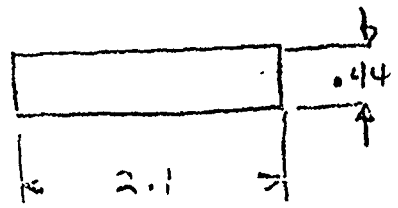
$$f_b = \frac{86.8(1.5)}{1.92} = 67.8$$

$$f_A = \frac{43.4}{2.73} = 15.9$$

$f = 83.7$ KSI

Assume $F_{TY} = 100$ $\quad MS = \frac{100}{83.7} - 1 = \underline{+.20}$

CHECK UNSUPPORTED ELEMENT AT FORKLIFT CUTOUT.



$$I = \frac{2.1(.44)^3}{12} = .0149$$

.085

$$A = 2.1(.44) = .924$$

$$\rho = \left(\frac{.0149}{.924}\right)^{1/2} = .127$$

$$f_{CR} = \frac{\pi^2 E}{\left(\frac{L}{\rho}\right)^2} = \frac{286(10)^6}{\left(\frac{13}{.127}\right)^2} = \frac{286(10)^6}{1.04(10)^4} = 27{,}500$$

TRICON

RACKING - DOOR SIDE

LOWER SIDE RAIL

ASSUME $P = 43.4 - 23.4(.45) = 33.0^{K}$

$f_{AXIAL} = \frac{33.0}{2.73} = 12.1$ KSI

$P_{LOWER\ CHORD} = 12.1\,(.924) = 11.2$ KIPS

$P_{WEB} = 12.1\,(4.2)(.1875) = 9.54^{K}$

ASSUME OUTER CHORD CARRIES HALF

$P'_{LC} = .5(9.54) = 4.77^{K}$

$P_T = 11.2 + 4.8 = 16.0^{K}$

$f = \frac{16.0^{K}}{.924} = 17.4$ KSI

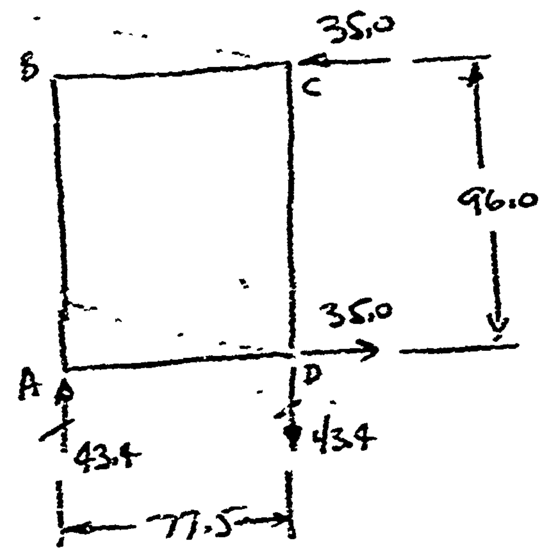
$M.S. = \frac{27.5}{17.4} - 1 = +.58$

THIS CHORD IS SUBJECT TO HANDLING DAMAGE AND THE OPERATING CRITERIA SHOULD BE REVIEWED WITH THIS IN MIND.

JOT 5-7-71

TRICON

RACKING - BLIND SIDE



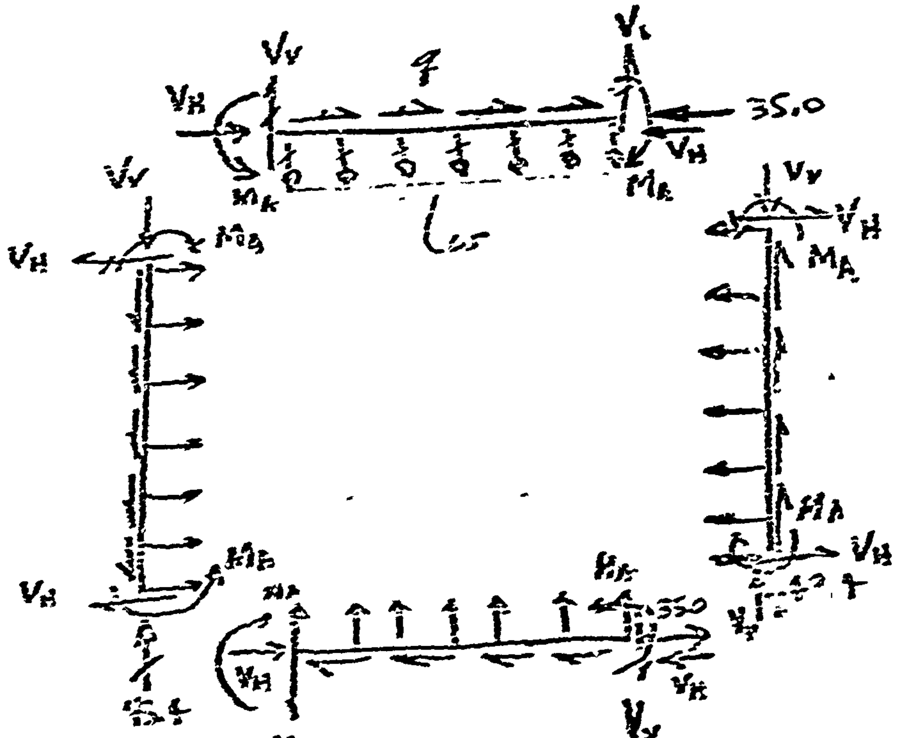
$q = \frac{35.0}{77.5-14.0} = 550 \frac{LB}{IN}$

$V_V = \frac{\cancel{450}\,100\,(77.5)}{2} = \cancel{17.5}\ 3.88^K$

$V_H = \frac{\cancel{450}\,100\,(96.0)}{2} = \cancel{21.6}\ 4.8^K$

ASSUME FIXED ENDS

$M_A = \frac{wl^2}{12} = \frac{450(96)(96)}{12} = 345$ IN-K

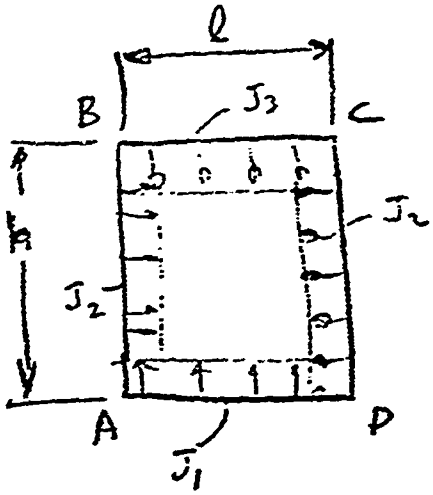


NOTE: THE UNIFORM LOAD ACTING ON THE BEAMS DOES NOT ASSU[ME] ANY COMPRESSION CA[PACITY] IN THE RODS.

w = 73 LB/IN USE w = 100 LB/IN (SEE P. 15?)

TRICON

RACKING LOAD - BLIND SIDE



KLEINLOGEL FRAME 106-

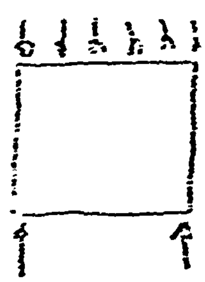
$$k_1 = \frac{J_3}{J_1}$$

$$k_2 = \frac{J_3}{J_2}\left(\frac{h}{l}\right)$$

$$K_1 = 2k_2 + 3$$

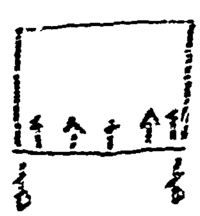
$$K_2 = 3k_1 + 2k_2$$

$$F_1 = K_1 K_2 - k_2^2$$



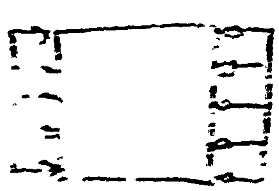
$$M_A = M_D = +\frac{ql^2}{4}\cdot\frac{k_2}{F_1}$$

$$M_B = M_C = -\frac{ql^2}{4}\cdot\frac{K_2}{F_1}$$



$$M_A = M_D = -\frac{ql^2}{4}\cdot\frac{k_1 K_1}{F_1}$$

$$M_B = M_C = +\frac{ql^2}{4}\cdot\frac{k_1 k_2}{F_1}$$



$$M_A = M_D = -k_2\left[\frac{\mathcal{L}K_1 - \mathcal{R}k_2}{F_1}\right]$$

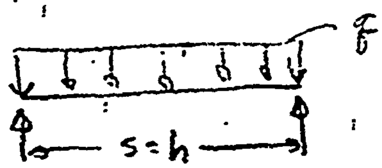
$$M_B = M_C = -k_2\left[\frac{\mathcal{R}K_2 - \mathcal{L}k_2}{\text{[illegible]}}\right]$$

TRICON

RACKING LOAD - BLIND SIDE

FROM KLEINLOGEL p. 441

$$\mathfrak{L} = \mathfrak{R} = \frac{qs^2}{4}$$



ASSUME $I_2 = I_3 = 9.45$ $\quad I_1 = 27.4$

$$\therefore M_A = M_D = \frac{ql^2}{4}\left(\frac{k_2}{F_1}\right) - \frac{ql^2}{4}\left(\frac{k_1 K_1}{F_1}\right) - k_2\left[\frac{\frac{qh^2}{4}(K_1 - k_2)}{F_1}\right]$$

$$= \frac{ql^2}{4}\left[\frac{k_2 - k_1 K_1 - k_2(K_1 - k_2)\left(\frac{h^2}{l^2}\right)}{F_1}\right]$$

$$M_B = M_C = -\frac{ql^2}{4}\left(\frac{K_2}{F_1}\right) + \frac{ql^2}{4}\left(\frac{k_1 k_2}{F_1}\right) - k_2\left[\frac{\frac{qh^2}{4}(K_2 - k_2)}{F_1}\right]$$

$$= \frac{ql^2}{4}\left[\frac{-K_2 + k_1 k_2 - k_2(K_2 - k_2)\left(\frac{h^2}{l^2}\right)}{F_1}\right]$$

TRACON

RACKING LOAD - BLIND SIDE

$$k_1 = \frac{9.45}{27.4} = .345 \qquad k_2 = \frac{9.45}{27.4}\left(\frac{96.0}{77.5}\right) = .426$$

$$K_1 = 2k_2 + 3 = 2(.426) + 3 = 3.86$$

$$K_2 = 3k_1 + 2k_2 = 3(.345) + 2(.426) = 1.890$$

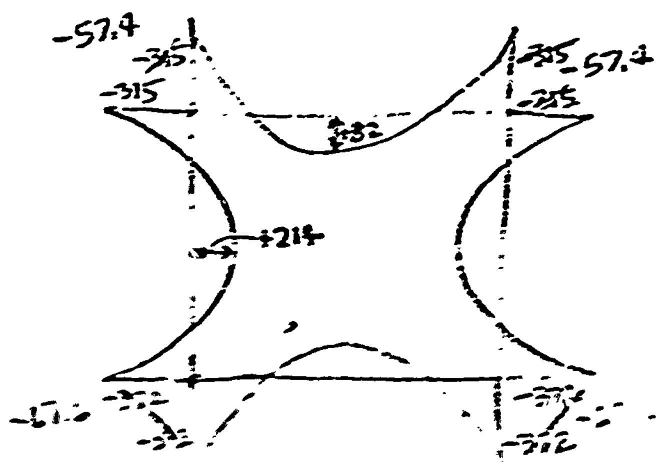
$$F_1 = K_1K_2 - k_2^2 = 3.86(1.89) - (.426)^2 = 7.12$$

$$M_A = M_D = \frac{\cancel{550}\,100\,(77.5)^2}{4}\left[\frac{.426 - .345(3.86) - .426(3.86 - .345)\left(\frac{96.0}{77.5}\right)^2}{7.12}\right]$$

$$M_A = M_D = \frac{\cancel{550}\,100\,(77.5)^2}{4}\left(\frac{-3.21}{7.12}\right) = \cancel{-372}\ -67.6 \text{ IN}\cdot\text{K}$$

$$M_B = M_C = \frac{\cancel{550}\,100\,(77.5)^2}{4}\left[\frac{-1.89 + .345(.426) - .426(1.89 - .426)(1.54)}{7.12}\right]$$

$$M_B = M_C = \cancel{675}\ 123\left(\frac{-2.70}{7.12}\right) = \cancel{-315}\ -51.4 \text{ IN}\cdot\text{K}$$



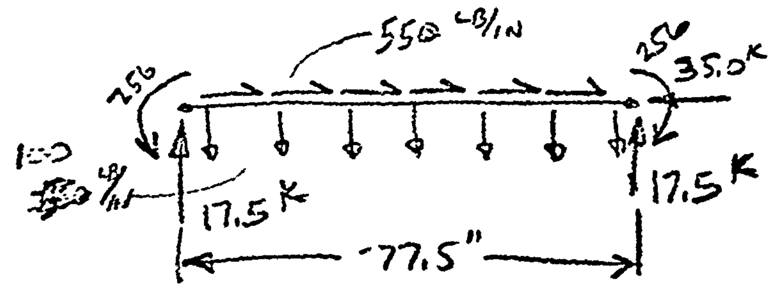
$$\Delta M_1 = \frac{wl^2}{8} = \frac{100(77.5)^2}{8} = 75.0$$

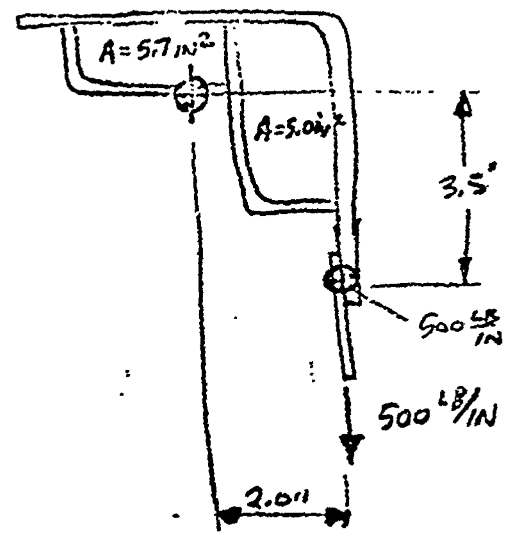
$$\Delta M_2 = \frac{wl^2}{8} = \frac{100(96.0)^2}{8} = 115.$$

$$\frac{wl_1^2}{12} = \frac{100(77.5)^2}{12} = 50.0$$

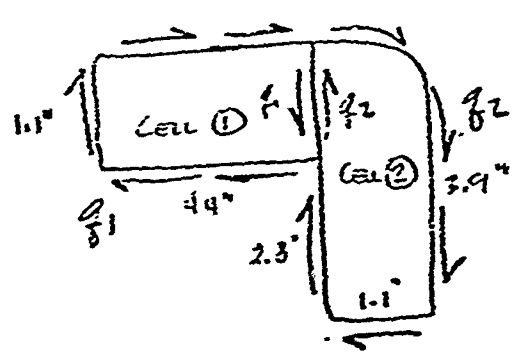
TRICON

RACKING – TOP RAIL – BLIND SIDE





ANALYZE TORSION AS TWO CELL BEAM:



$$q_1 = \frac{1}{2}\left[\frac{(a_{20}A_1 + a_{12}A)}{a_{20}A_1^2 + a_{12}A^2 + a_{10}A_2^2}\right]T$$

$$q_2 = \frac{1}{2}\left[\frac{a_{10}A_2 + a_{12}A}{a_{20}A_1^2 + a_{12}A^2 + a_{10}A_2^2}\right]T$$

$$J = 4\left[\frac{a_{20}A_1^2 + a_{12}A^2 + a_{10}A_2^2}{a_{10}a_{12} + a_{12}a_{20} + a_{20}a_{10}}\right]$$

$$\theta = \frac{T}{GJ}$$

$A = A_1 + A_2$

$A_1 = 5.7$, $A_2 = 5.0$ } $A = 10.7$

Broken ($A = 5.7$)

TRICON

RACKING - TOP RAIL - BLIND SIDE

$$a_{10} = \frac{4.4(2)+1.1}{.1875} = \frac{9.9}{.1875} = 52.8$$

$$a_{12} = \frac{1.1}{.1875} = 5.86$$

$$a_{20} = \frac{2(1.1)+3.9+2.8}{.1875} = \frac{8.9}{.1875} = 47.5$$

$$q_1 = \left[\frac{\overset{271}{47.5(5.7)} + \overset{62.7}{5.86(10.7)}}{\underset{1545}{47.5(5.7)^2} + \underset{673}{5.86(10.7)^2} + \underset{1320}{52.8(5.0)^2}}\right]\frac{T}{2} = \frac{334(T)}{(3538)2} = .0472T$$

3538

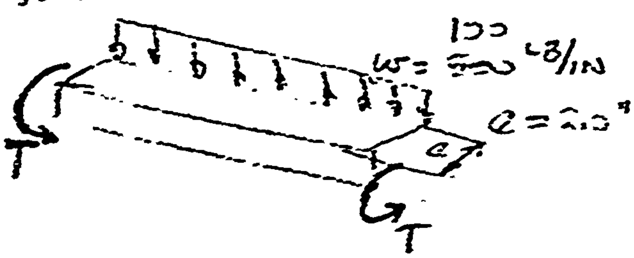
$$q_2 = \left[\frac{52.8(5.0) + \overset{264}{5.86(10.7)}}{3538}\right]\frac{T}{2} = \left[\frac{327}{3538}\right]\frac{T}{2} = .0461\,T$$

$$J = 4\left[\frac{3538}{\underset{309}{52.8(5.85)} + \underset{279}{47.5(5.85)} + \underset{2510}{52.8(47.5)}}\right] = 4\left[\frac{3538}{3098}\right] = 4.56$$

Assume $T = \frac{wle}{2}$

$$\therefore T = \frac{\overset{100}{\cancel{550}}(77.5)(2)}{2}$$

$T = \overset{7.75}{\cancel{42.6}}\ IN^K$

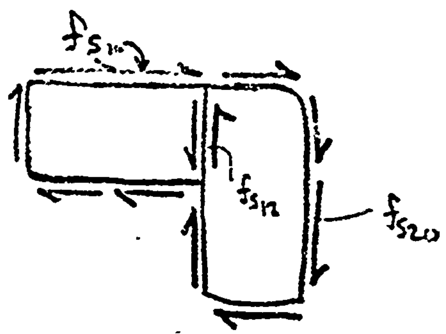


$q_1 = .0472(\overset{7.75}{\cancel{42.6}}) = \overset{.365}{\cancel{2.01}}$ K/IN

$q_2 = .0461(\overset{7.75}{\cancel{42.6}}) = \overset{.357}{\cancel{1.97}}$ K/IN

TRICON

RACKING – TOP RAIL – BLIND SIDE



$$f_{s10} = \frac{q_1}{t_1} = \frac{\cancel{2.01}\ ^{K}/_{IN}}{.1875_{IN}} = 10.7 \text{ KSI}$$

$$f_{s20} = \frac{q_2}{t_2} = \frac{\cancel{1.97}}{.1875} = 10.5 \text{ KSI}$$

$$f_{12} = \frac{q_1 - q_2}{t_1} = \frac{.04}{.1875} \approx 0$$

$$\theta = \frac{T}{GJ} = \frac{\overset{7.75}{\cancel{42.6}}}{11(10)^3(4.56)} = \overset{.155}{\cancel{.85}}(10)^{-3} = .00\overset{155}{\cancel{085}} \text{ RAD}$$

$$\text{TOTAL ROTATION} = \frac{\theta \ell}{2} = \frac{.000\overset{155}{\cancel{85}}(77.5)}{2} = \overset{.006}{\cancel{.033}} \text{ RAD}$$

CHECK MAXIMUM BENDING + AXIAL STRESS

$$f = \frac{35.0}{4.25} + \frac{\overset{57.4}{\cancel{256}}(3.5)}{9.45} = 8.3 + \overset{21.2}{\cancel{95.0}} = \overset{29.5}{\cancel{103.3}}$$

TOO HIGH, BUT COMPRESSION IN RODS RELIEVES LOADS AND REDUCES MOMENTS CONSIDERABLY.

TRICON

RACKING – TOP RAIL – BLIND SIDE

ASSUME $e = 2.0''$

$\therefore M = 2.0(35.0) = 70.0$ IN.K

$$f_{b_1} = \frac{70.0(4.4)}{18.6} = 16.5$$

$$f_{b_2} = \frac{70.0(3.5)}{9.45} = 26.0$$

$$f_A = \frac{35.0}{4.24} = 8.3$$

$$f_{TOTAL} = 8.3 + 26.0 = 34.3$$

ASSUME $F_{TY} = 40.0$

$$MS = \frac{40.0}{34.3} - 1 = +.17$$

TRICON

RACKING - BLIND SIDE-BOTTOM RAIL

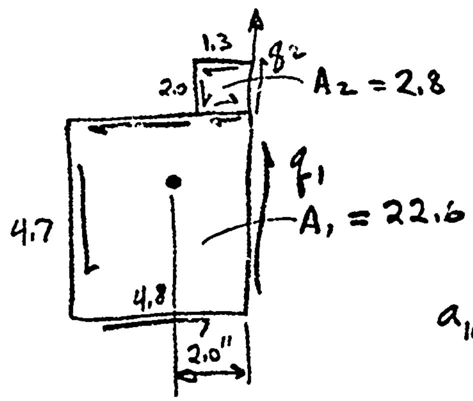
CHECK MAXIMUM STRESS:

$$f = \frac{35.0}{4.71} + \frac{\overset{\text{67.[illegible]}}{\cancel{305}}\,(4.5)}{27.4} = 7.4 + \overset{11.1}{\cancel{50.0}} = \overset{18.5}{\cancel{57.4}}\ \text{KS}$$

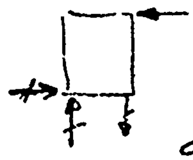
TRICON

RACKING — BLIND SIDE-BOTTOM RAIL —

LOADING SAME AS DOOR HEADER BLIND SIDE IF REACTED ON OPPOSITE SIDE



$A_1 = 22.6$
$A_2 = 2.8$
$A = 25.4$



$a = \frac{ds}{t}$

$$a_{10} = \frac{2(4.7)+4.8+3.5}{.1875} = \frac{17.7}{.1875} = 94.4$$

$$a_{12} = \frac{1.3}{.1875} = 6.94$$

$$a_{20} = \frac{2.0+1.3}{.125} + \frac{2.0+1.3}{.1875} = 26.4 + 17.6 = 44.0$$

$$q_1 = \frac{T}{2}\left[\frac{44(22.6)+6.94(25.4)}{44.0(22.6)^2+6.94(25.4)^2+94.4(2.8)^2}\right] = \frac{T}{2}\left[\frac{1170}{27730}\right] = .0211\,T$$

$$q_2 = \frac{T}{2}\left[\frac{94.4(2.8)+6.94(25.4)}{27730}\right] = \frac{T}{2}\left[\frac{440}{27730}\right] = .008\,T$$

$$J = 4\left[\frac{27730}{94.4(6.94)+44.0(6.94)+94.4(44.0)}\right] = \frac{4(27730)}{5109} = 21.7$$

$$\text{ASSUME } T = \frac{wle}{2} = \frac{\cancel{550}\ 100\,(77.5)(2.0)}{2} = \cancel{42.6}\ 7.75 \text{ IN}\cdot\text{K}$$

$$q_1 = .0211\,(\cancel{42.6}\ 7.75) = \cancel{.90} \text{ K/IN} \qquad f_{s_1} = \frac{\cancel{.803}}{.1875} = 4.3 \text{ KSI}$$

$$q_2 = .008\,(\cancel{42.6}\ 7.75) = \cancel{.34} \text{ K/IN} \qquad f_{s_2} = \frac{\cancel{.34}}{.125} = 470 \text{ KSI}$$

$$\theta = \frac{T}{JG} = \frac{\cancel{42.6}\ 7.75}{11(10)^3(21.7)} = \cancel{.000179}\ .0000326 \text{ RAD}$$

[illegible] $= \frac{\theta l}{2} = \frac{.000179(77.5)}{2}$ [illegible]

TRICON

RACKING - BLIND SIDE-POST

ASSUME $q_1 = .0472\,T$, $q_2 = .0461\,T$ } SAME AS TOP RAIL (CONSERVATIVE)

$$T = \frac{wle}{2} = \frac{\overset{100}{\cancel{550}}(96)(2)}{2} = \overset{9.61}{\cancel{52.9}}\ \text{IN-K}$$

$$q_1 = .0472\left(\overset{9.61}{\cancel{52.9}}\right) = \overset{.455}{\cancel{2.50}}\ \text{K/IN} \qquad f_{s_1} = \frac{\overset{.455}{\cancel{2.50}}}{.1875} = \overset{2.42}{\cancel{13.3}}\ \text{KSI}$$

$$q_2 = .0461\left(\overset{9.61}{\cancel{52.9}}\right) = \overset{.444}{\cancel{2.44}}\ \text{K/IN} \qquad f_{s_2} = \frac{\overset{.444}{\cancel{2.44}}}{.1875} = \overset{2.36}{\cancel{13.0}}\ \text{KSI}$$

CHECK MAXIMUM STRESS

$$f = \pm\frac{43.4}{4.9} \pm \frac{\overset{67.6}{\cancel{305}}(4.9)}{22.1} = 8.9 + \overset{15.0}{\cancel{67.6}} = \overset{23.9}{\cancel{76.5}}\ \text{KSI}$$

(ABOUT 7.0" ...)

$$\text{OR } f = 8.9 \pm \frac{\overset{67.6}{\cancel{305}}(4.6)}{18.1} = 8.9 + \overset{17.2}{\cancel{77.5}} = \overset{26.1}{\cancel{86.4}}\ \text{KSI}$$

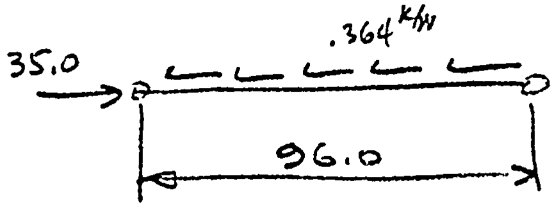
(ABOUT 6.5" SIDE)

NOTE: BENDING MOMENTS ARE REDUCED CONSIDERABLY BY THE COMPRESSION LOAD IN THE ROD.

TRICON

RACKING

SIDE RACKING - UPPER SIDE RAIL



ASSUME $e = 2.0''$

$M = 2(35.0) = 70.0$

$f_b = \dfrac{70.0\,(3.5)}{(9.45)} = 25.9$ KSI

$f_a = \dfrac{35.0}{4.24} = 8.3$ KSI

$f_{TOTAL} = 34.2$ KSI]

ASSUME $F_{TY} = 40.0$ KSI

$MS = \dfrac{40.0}{34.2} - 1 = +.17$

TRICON

SIDE WALL LOAD RH & LH

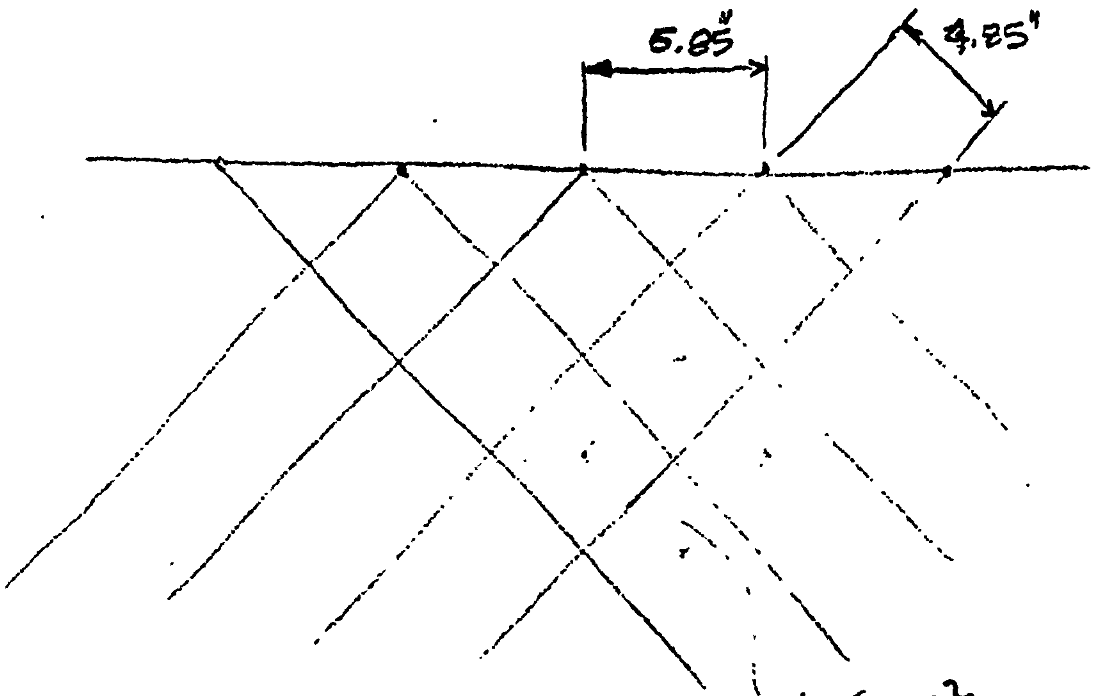
ASSUME $a = 96\text{-}14 = b = 96\text{-}14$ $a/b = 1.0$

$P = 5460^{\#}$ $a = b = 82''$

$A = 8100 \text{ IN}^2$

$p = \frac{5460}{8100} = .675$ PSI

CHECK WITH 1/4" RODS AT $S = 6.85''$



LENGTH OF ROD = $9.7'' = 2(4.85'')$

AREA OF $\frac{1}{4}''$ ROD $= .049$

ROD VOLUME $= 2(4.85)(.049) = .475 \text{ IN}^3$

SPREAD OVER 23.5 IN^2 $\therefore$ $\bar{t} = \frac{.475}{23.5} = .0202$

TRICON

SIDE WALL LOAD RH OR LH

$$w_{MAX} = n_1\, a \left(\frac{qa}{Et}\right)^{1/3}$$

$$s_{MAX} = n_2 \left[E\left(\frac{qa}{t}\right)^2\right]^{1/3}$$

$n_1 = .318 \qquad n_2 = .356 \qquad \bar{t} = .020$

$$w_{MAX} = .318\,(90)\left[\frac{.675(90)}{29(10)^6(.020)}\right]^{1/3} = 28.6\left[105(10)^{-6}\right]^{1/3}$$

$$= 28.6(4.71)(10)^{-2} = 1.35'' \qquad \left(\tfrac{1}{4}'' @ 6.85''\right)$$

$$s_{MAX} = .356\left[29(10)^6\left(\frac{.675(90)}{.02}\right)^2\right]^{1/3} = .356\left[268(10)^{12}\right]^{1/3}$$

$$= .356(6.45)(10)^4 = 23{,}000 \text{ psi} \quad \left(\tfrac{1}{4}'' @ 6.85''\right)$$

CHECK 3/16" ROD @ 5.0"

$$A_{3/16} = .0276 \qquad \bar{t} = \frac{7.0(.0276)}{12.25} = .0158$$

$$W_{MAX} = 28.6\left[75.0\left(\frac{.028}{.0158}\right)(10)^{-6}\right]^{1/3} = 28.6(10)^{-2}(5.1) = 1.46''$$

$\left(3/16'' @ 5.0''\right)$

$$s_{MAX} = .356\left[29(10)^6\left[\frac{60.8}{.0158}\right]^2\right]^{1/3} = .356\left[429(10)^{12}\right]^{1/3} = 26{,}900 \text{ psi}$$

TRICON

BLIND SIDE WALL LOAD

ASSUME $a = 90.$ $b = 71.0$ $a/b = 1.27$

$P = 8100$ LB $A = 90(71) = 6400$ IN^2

$$p = \frac{8100}{6400} = 1.27 \text{ PSI}$$

STRESSES AND DEFLECTIONS MAXIMUM AT $\approx a/b = 1.0$

CHECK $\frac{1}{4}$" RODS @ 5.85" $\bar{t} = .020$

198 (10)$^{-6}$

$$W_{MAX} = 28.6\left[105.0\left(\frac{1.27}{.675}\right)(10)^{-6}\right]^{1/3} = 1.67''$$

5.94 (10)$^{-2}$

($\frac{1}{4}$" RODS @ 5.0")

9.80 (10)^{4}

$$S_{MAX} = .356\left[29(10)^6\left(3040\left(\frac{1.27}{.675}\right)\right)^2\right]^{1/3} = .356\left[950(10)^{12}\right]^{1/3} = 34,900 \text{ PSI}$$

5780

32.8 (10)^{6}

~~CHECK $\frac{3}{16}$" RODS @ 5.0" $\bar{t} = .0158$~~

250 (10)$^{-6}$

$$\cancel{W_{MAX} = 28.6\left[141(10)^{-6}\left(\frac{.028}{.0150}\right)\right]^{1/3} = 1.30''}$$

6.3 (10)$^{-2}$

($\frac{3}{16}$" ROD @ 5.0")

7200

$$\cancel{S_{MAX} = .356\left[29(10)^6\left(4080\left(\frac{.028}{.0158}\right)\right)^2\right]^{1/3} = 41,400 \text{ PSI}}$$

52.3 (10)^{6}

1540 (10)^{12}

11.6 (10)^{4}

JOT 4-20-71

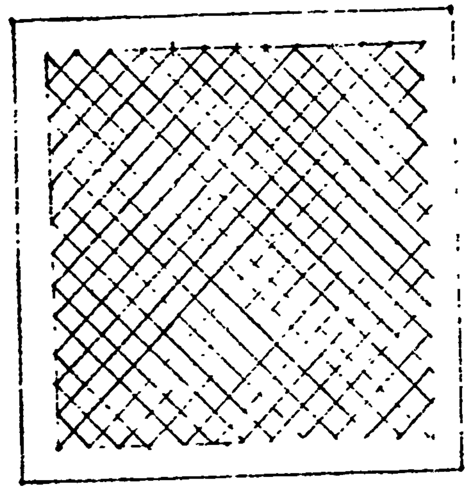
TRICON

ROOF LOAD

$P = 660^{\#}$ $A = 12'' \times 24'' = 288\ in^2$

$p = \frac{660}{288} = 2.29\ psi$

NOT CRITICAL BY INSPECTION SINCE SIDE WALLS CAN CARRY 1.27 PSI OVER ENTIRE AREA

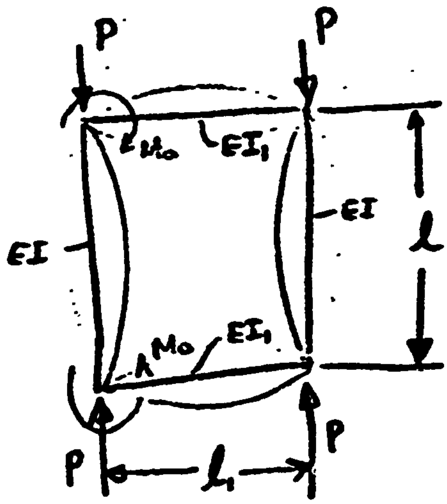


SIDE WALL CONFIGURATION

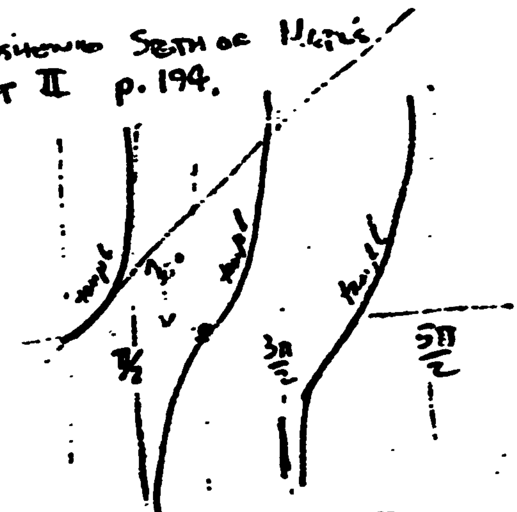
TRICON

STACKING LOAD

DOOR POST



TIMOSHENKO SETH OF NOTES
PART II p. 194.



SIDESWAY RESTRAINED.

IT IS SHOWN THAT:

$$\tan\frac{p\ell}{2} + \left(\frac{I}{I_1}\right)\left(\frac{\ell_1}{\ell}\right)\frac{p\ell}{2} = 0 \qquad P_{CR} = p^2 EI$$

$I = 1.95 \quad I_1 = 18.7 \quad \ell_1 = 77.5 \quad \ell = 96.0$

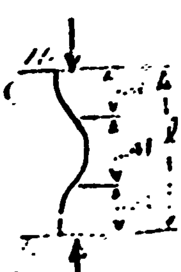
$$\left(\frac{I}{I_1}\right)\left(\frac{\ell_1}{\ell}\right) = \left(\frac{1.95}{18.7}\right)\left(\frac{77.5}{96.0}\right) = .084$$

(RESISTANCE OF HORIZONTAL MEMBERS IS SIGNIFICANT)

$$\therefore \tan\frac{p\ell}{2} + .084\left(\frac{p\ell}{2}\right) = 0 \quad \text{OR} \quad \tan\left(\frac{p\ell}{2}\right) = -.084\left(\frac{p\ell}{2}\right)$$

WHEN $\tan(X)$ = A SMALL NEGATIVE NUMBER, $X \to \pi$

ASSUME $X = .95\pi = 2.98$ RAD $= 171°$ $\tan 171° = -.158$; $-.084(2.98) = -$
$X = .90\pi = 2.83$ RAD $= 162°$ $\tan 162° = -.325$; $-.084(2.83) = -$
$X = .93\pi = 2.92$ RAD $= 167°$ $\tan 167° = -.231$; $-.084(2.92) = -$



CLOSE ENOUGH - USE $\left(\frac{p\ell}{2}\right) = .93\pi$ $\therefore p = \frac{2(.93)\pi}{\ell}$; $p^2 = \frac{3.46}{\ell^2}$

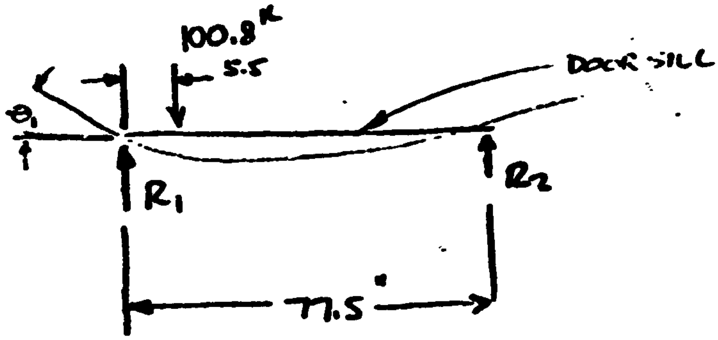
$$\therefore P_{CR} = \frac{3.46\pi^2 EI}{\ell^2} \quad \text{OR} \quad P_{CR} = \frac{\pi^2 EI}{.289(\ell^2)} = \frac{\pi^2 EI}{(.538\ell)^2}$$

$\therefore \ell_{EFF} = .538\ell$ (86.5% FIXED)

TRICON

STACKING LOAD

DOOR POST



$$R_1 = 100.8\left(\frac{72.0}{77.5}\right) = 93.5^K$$

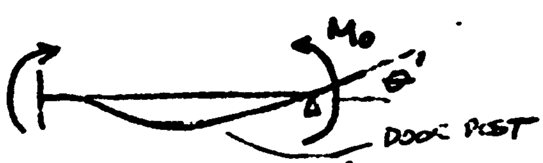
$$R_2 = 7.3^K$$

CRITICAL EULER BUCKLING LOAD. (END FIXITY C = 3.46)

$$P_{CR} = \frac{C\pi^2 EI}{l^2} = \frac{3.46(9.86)(29)(10)^6(1.95)}{96(96)} = 209.^K$$

$$\theta_1 = \frac{1}{6}\,\frac{W}{EI}\left[\overset{5590}{72(77.5)} - \overset{4920}{\frac{(72)^3}{77.5}}\right] = \frac{100.8}{6(29)(10)^3(19.0)}\left[770\right]$$

$$= \frac{77500\,(10)^{-3}}{3310} = .0234 \text{ RAD}$$



$$\theta' = \frac{M_0\, l}{4EI}$$

ASSUME $\theta_1 = \theta'$ $\therefore$ $M_0 = \dfrac{4\theta' EI}{l}$

$$M_0 = \frac{4(.0234)(29)(10)^3(1.95)}{96} = 56.1 \text{ IN}\cdot\text{K}$$

TRILON

STACKING LOAD

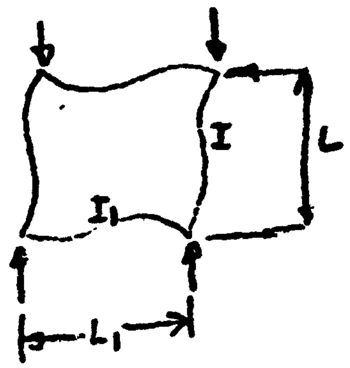
DOOR POST

$$f_{max} = -\frac{93.5}{2.82} \pm \frac{56.1\,(1.6)}{1.95} = -33.2 \pm 46.1 = -79.3 \text{ ksi}$$

MUST USE 100 KSI = F_{TY} STEEL TO GET

F_{TY} = 85.0 KSI AFTER WELDING

CHECK WITH BRESSLER & LIN p. 362



$$\left(\frac{I_1}{I}\right)\left(\frac{L}{L_1}\right) = \left(\frac{18.7}{1.95}\right)\left(\frac{96.0}{77.5}\right) = 11.9$$

$$\frac{L}{L_e} = 1.85$$

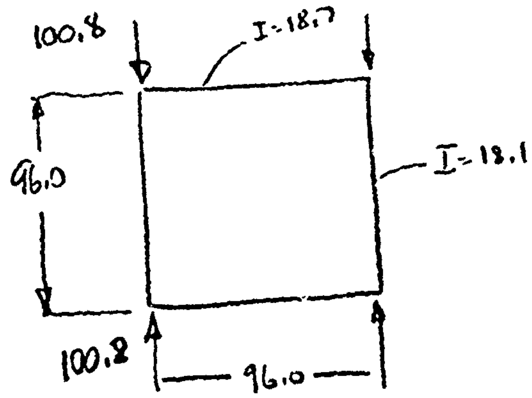
$L_e = .541\,L \rightarrow$ USED $.538\,L$

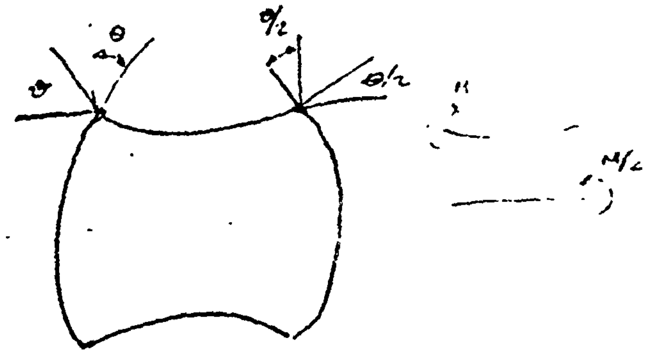
FOR THIS CASE, SIDESWAY IS PREVENTED BY SHEAR STIFFNESS OF THE PANEL DIAGONALS

TRICON

STACKING LOAD

BLIND SIDE POST





$$\left(\frac{I}{I_1}\right)\left(\frac{l_1}{l}\right) = \left(\frac{18.1}{18.7}\right)\left(\frac{77.5}{96.0}\right) = .78$$ (RESISTANCE OF HORIZONTAL MEMBERS NOT SIGNIFICANT)

ASSUME $P_{CR} = \frac{\pi^2 EI}{l^2} = \frac{9.86(29)(10)^6(18.1)}{(96)(96)} = 561.^K$

ASSUME $e = 2.0''$

$M = 2.0(100.8) = 202$ IN.K

$f_b = \frac{202(4.9)}{22.1} = 45.0$ ksi

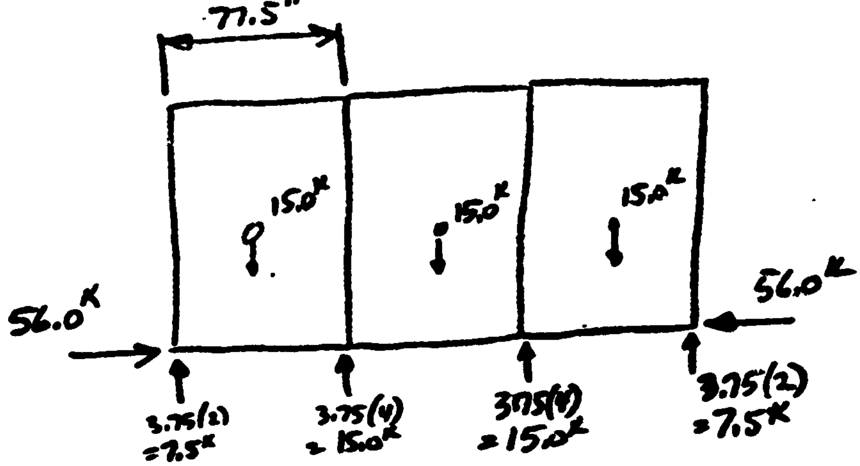
$f_a = \frac{100.8}{4.9} = 20.6$

$f_{TOTAL} = 65.6$ ksi

ASSUME $F_{TY} = 75.0$ $MS = \frac{75.0}{65.6} - 1 = +.14$

TRICON

HORIZONTAL RESTRAINT



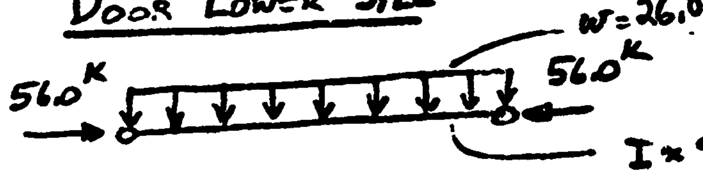
ASSUME 15.0^K GROSS WEIGHT DISTRIBUTED EQUALLY OVER LOWER DOOR SILLS AND SIDE RAILS.

$$w = \frac{15.0^K}{2(77.5)+2(96.0)} = \frac{15,000}{347} = 43.3 \text{ LB/IN}$$

155
192

USE $w = 50.0$ LB/IN

DOOR LOWER SILL



$I = 9.00 \text{ IN}^4$ (MINIMUM)

$$j = \sqrt{\frac{EI}{P}} = \left[\frac{29(10)^6(9.0)}{56.0(10)^3}\right]^{1/2} = \left[4.65(10)^3\right]^{1/2} = 68.0$$

$$U = \frac{l}{j} = \frac{77.5}{68.0} = 1.14 \text{ RAD} = 65.4°$$

$$\frac{U}{2} = \frac{1.14}{2} = .57 \text{ RAD} = 32.7° \qquad \sec\frac{U}{2} = 1.188$$

$$M_{MAX} = wj\left(\sec\frac{U}{2} - 1\right)$$

$$y_{MAX} = -\frac{wj^2}{P}\left(\sec\frac{U}{2} - 1 - \frac{U^2}{8}\right)$$

TRICON

HORIZONTAL RESTRAINT

DOOR LOWER SILL

$$M_{max} = 50(68)(.188) = 640 \text{ IN}\cdot\text{LB} = .64 \text{ IN}\cdot\text{K}$$

$$y_{max} = -\frac{50(4650)}{56000}(1.188-1-.162) = \frac{50(4650)(.026)}{56,000}$$

$$y_{max} = .109'' < .25'' \quad \text{OK}$$

VERTICAL BENDING AXIS

$$f_{MAX} = \frac{56.0}{4.01} \pm \frac{.64(3.2)}{19.0} = 13.9 \pm .1 = 14.0 \text{ ksi}$$

CHECK SECTION AT FORK LIFT CUT OUT (LOWER ELEMENT)

$$\text{Assume } f = 14.0 \text{ ksi} \quad l = 13.0'' \quad \rho = \left(\frac{\overset{.147}{.27}}{1.84}\right)^{1/2} = .384$$

$$f_{CR} = \frac{\pi^2 E}{\left(\frac{l}{\rho}\right)^2} = \frac{9.86(29.0)(10)^6}{\underbrace{\left(\frac{13}{.384}\right)^2}_{33.8}} = \frac{286(10)^6}{1,140} = 251,000.$$

$$f_{CR} = 251 \quad \text{OK}$$

BLIND SIDE RAIL (SILL)

$$I = 17.1 \quad A = 4.71$$

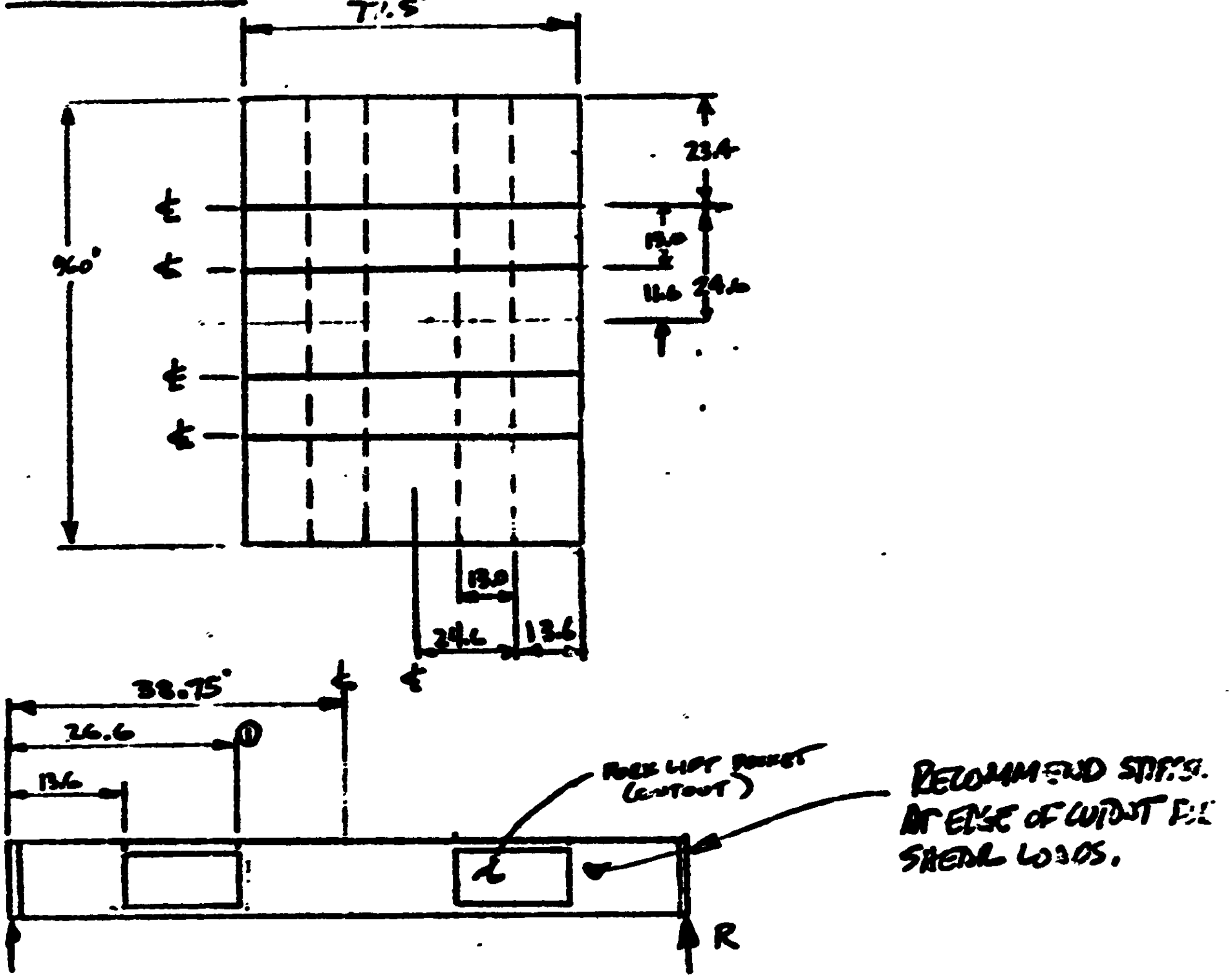
$$\text{Assume } e = 2.0'' \quad M = 56(2) = 112 \text{ IN}\cdot\text{K}$$

$$f = \frac{56.0}{4.71} + \frac{112(3.0)}{17.1} = 11.9 + 19.6 = 31.5$$

$$\text{Assume } F_{TY} = 40. \quad MS = \frac{40}{31.5} - 1 = +.27$$

TRICON

FLOOR LOAD



ASSUME MAXIMUM RUNNING LOAD ON FLOOR BEAM w IS AS FOLLOWS:

$$p_i = \frac{30{,}000}{(96-4)(77.5-4)} = \frac{30{,}000}{6{,}760} = 4.44 \text{ psi}$$

92 73.5

MAXIMUM LOADED WIDTH $= \dfrac{23.4+13.0}{2} = 18.2$ IN

$\therefore\ w = 4.44(18.2) = 80.6$ LB/IN

ASSUME SIMPLE SUPPORTS:

$$M_{MAX} = \frac{wl^2}{8} = \frac{80.6\,(77.5)^2}{8} = 60.5 \text{ IN}\cdot\text{K}$$

$$R = \frac{wl}{2} = \frac{80.6(77.5)}{2} = 3120\ \#$$

TRICON

FLOOR LOAD

$$f_{b_{(℄)}} = \frac{Mc}{I} = \frac{60.5\,(2.5)}{6.7} = 22.6 \text{ KSI}$$

CHECK AT EDGE OF CUTOUT NEAREST ℄.

$$M_{①} = \frac{w\ell}{2}\left(x - \frac{x^2}{\ell}\right) \qquad x = 26.6$$

$$= \frac{80.6(77.5)}{2}\left(26.6 - \frac{(26.6)^2}{77.5}\right) = 3120(17.5) = 54.5 \text{ IN·K}$$

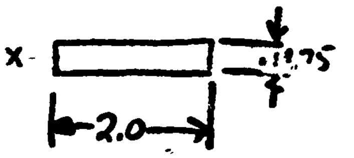
7.07

9.1

$$\text{ASSUME } P_{CHD} = \frac{M}{d} = \frac{54.5}{5.0} = 10.9^{K}$$

$$A_{CHD} = 2.0(.1875) = .375$$

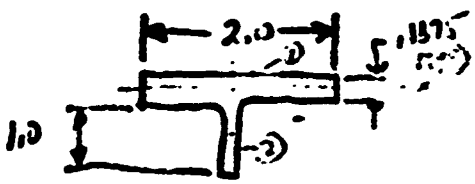
$$f_{CHD} = \frac{10.9}{.375} = 29.0 \text{ KSI}$$



$$I_x = \frac{2.0(.1875)^3}{12} = \frac{.0066}{6} = .0011$$

$$\rho = \left(\frac{.0011}{.375}\right)^{1/2} = (.00294)^{1/2} = .0541$$

$$\frac{\ell}{\rho} = \frac{13.0}{.0541} = 240 \quad \text{(UNSUPPORTED BY FLOOR)}$$



ELEM	A	y	Ay	Ay²	Ix
1	.375	0	0	0	.0011
2	.188	.5	.094	.047	.0158
	.563		.094	.047	.0169

$$\bar{y} = \frac{.094}{.563} = .167$$

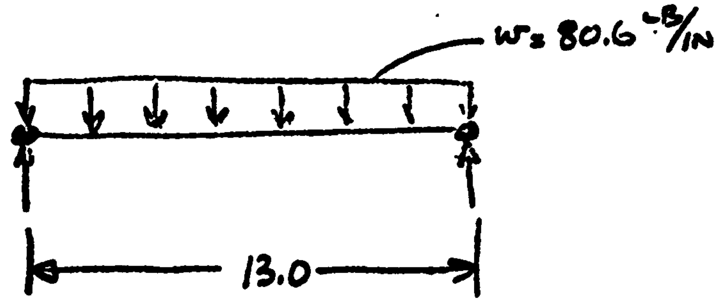
$$I = .0169 + .047 - .563(.167)^2 = .0482$$

$$\rho = \left(\frac{.0482}{.563}\right)^{1/2} = (.0856)^{1/2} = .292$$

TRICON

FLOOR LOAD

$$\frac{l}{\rho} = \frac{13.0}{.292} = 44.5$$



$$M_{max} = \frac{wl^2}{8} = \frac{80.6\,(13)^2}{8} = 1710 \text{ IN·LB}$$

$$f_b = \frac{1710(1.0)}{.0482} = 35,000 \text{ psi}$$

$$f_A = 29.0$$

$$f_{TOTAL} = 64.0 \text{ KSI}$$

Assume $F_{TY} = 75.0$

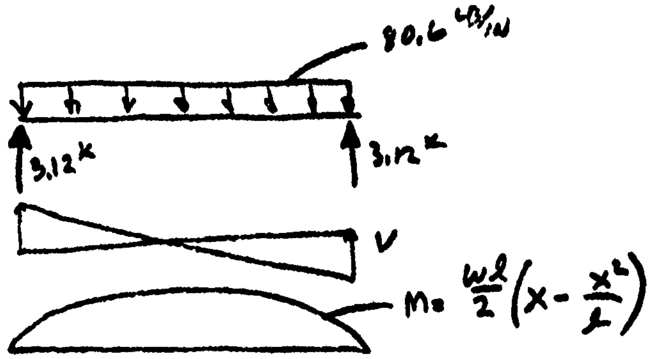
$$MS = \frac{75.0}{64.0} - 1 = \underline{\underline{+.17}}$$

JOT 5-7-71

TRICON

FLOOR LOAD

CHECK FLOOR BEAM DEFLECTION.



ASSUME $I = \text{CONST} = 6.5\ \text{IN}^4$

$f_{s\,max} = \frac{4}{3}\left(\frac{3.12}{.1875}\right) = 2.22\ \text{KSI}$

$$\delta_{CTR} = \frac{5}{384}\frac{(w)(l)^4}{EI} = \frac{5(80.6)\overset{36(10)^6}{(77.5)^4}}{384(29)(10)^6(6.5)} = \frac{14500}{72400} = .20''$$

CHECK LATERAL STABILITY

$$F_{CR} = K'E\left(\frac{b^2}{Ld}\right)$$

$b = 2.0$ $\quad E = 29(10)^6$

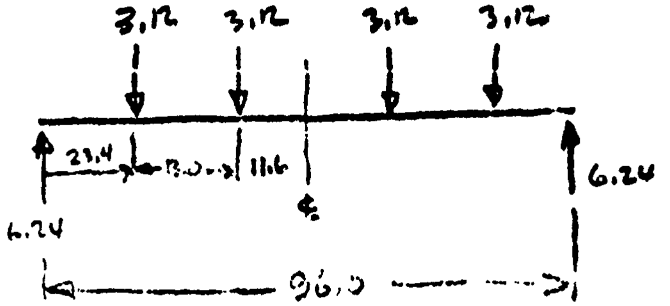
$d = 5.0$ $\quad K' = 2.20$

$L = 77.5$

$$F_{CR} = 2.2(29)(10)^6\left(\frac{4}{\underset{433}{5(77.5)}}\right) = 63.9(10)^6(1.03)(10)^{-2} = 659000$$

NOT CRITICAL FOR LATERAL STABILITY

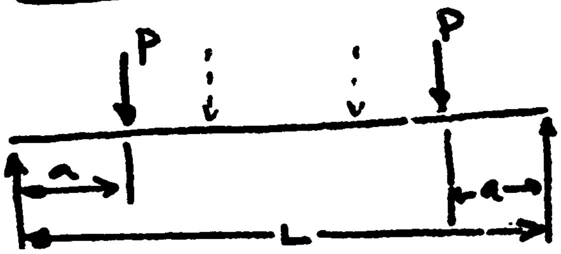
CHECK LOWER SIDE RAIL



FLOOR BEAM LOADS ARE APPROXIMATELY EQUAL

TRICON

FLOOR LOADS - LOWER SIDE RAIL



$$\delta_{CTR} = \frac{Pa}{24EI}\left(3L^2 - 4a^2\right)$$

$a_1 = 23.4 \quad a_2 = 36.4 \quad I = 15.0$

$P = 3.12^K \quad E = 29.0(10)^3\ KSI \quad L = 96.0$

$$\delta_1 = \frac{3.12(23.4)}{24(29)(10)^3(15.0)}\left[3\underset{27600}{\overset{9210}{(96)^2}} - 4\underset{2190}{\overset{550}{(23.4)^2}}\right]$$

25410

$$= \frac{73.0}{1.0420(10)^3}(25410) = .178$$

$$\delta_2 = \frac{3.12(36.4)}{10420(10)^3}\left[\underset{22300}{27600} - 4\underset{5300}{\overset{1325}{(36.4)^2}}\right] = 113.8\left(\frac{22.3}{1.042}\right)(10)^{-3}$$

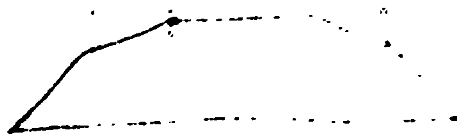
$$\delta_2 = .243''$$

$$\delta_{CTR} = .178 + .243 = .421''$$

NOTE: IF THERE EXISTS ANY LIMITATION ON THE DEFLECTION OF THE SIDE RAIL FOR THE FLOOR LOADING CONDITION, THIS COULD BE CRITICAL. ALSO, THE INTERIOR FLOOR BEAM CAN DEFLECT ABOUT .20 + .42 = .62". IF THIS TEST IS CONDUCTED, THE CORNER POSTS SHOULD BE SUPPORTED .62" ABOVE ANYTHING UNDER THE CENTER OF THE CONTAINER.

TRICON

FLOOR LOADS – LOWER SIDE RAIL



$M_1 = 6.24\,(23.4) = 146$ IN.K

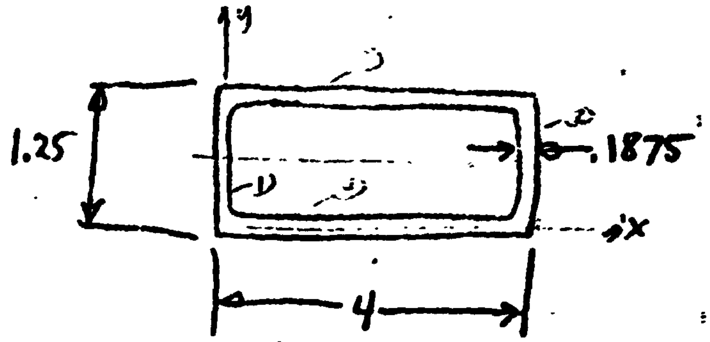
$M_2 = 6.24\,(36.4) - 3.12\,(13.0) = 187$ IN.K

$\quad 227 \qquad 40.5$

$$f_b = \frac{187\,(4.2)}{19.1} = 41.1 \text{ KSI}$$

TRICON

DOOR



ELEM	A	x	Ax	Ax²	y	Ay	Ay²	I_x	I_y
1	.167	0	.0	0	.62	.104	.064	.031	0
2	.167	4.0	.667	2.67	.62	.103	.064	.031	0
3	.75	2.0	1.50	3.00	1.25	.935	1.07	0	1.02
4	.75	2.0	1.50	3.00	0	0	0	0	1.02
	1.834		3.67	8.67		1.142	2.98	.062	2.04

$$\bar{X} = \frac{3.67}{1.83} = 2.0''$$

7.32

$$I_y = 2.04 + 8.67 - 1.83(2.0)^2 = 3.39 \text{ in}^4$$

$$\bar{y} = \frac{1.142}{1.83} = .625''$$

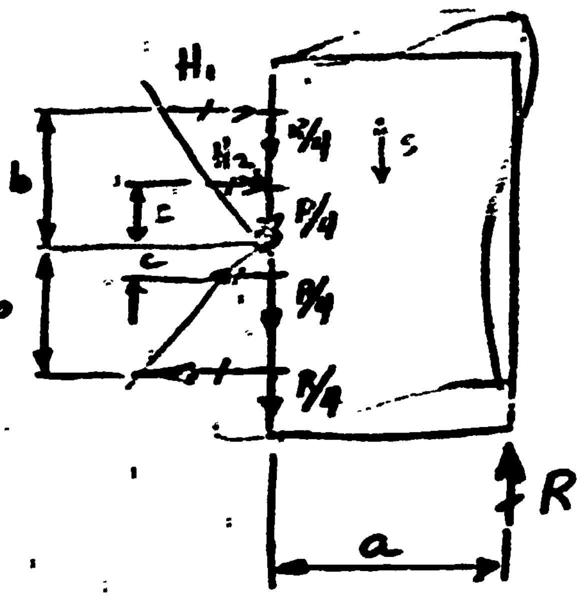
.720

$$I_x = .06 + 2.98 - 1.83(.625)^2 = 2.73 \text{ in}^4$$

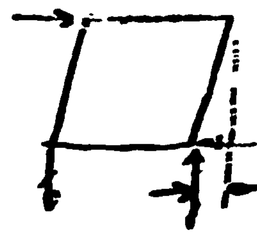
Triton

Door

Assume no diagonal bracing.



Find load R to deform door



$$2H_1(b) + 2H_2(c) = Ra \qquad H_2 = H_1\left(\frac{c}{b}\right) \text{ or } H_1 = H_2\left(\frac{b}{c}\right)$$

$$2H_1 b + 2H_1\left(\frac{c^2}{b}\right) = Ra$$

$$2H_1\left(b + \frac{c^2}{b}\right) = Ra$$

$$H_1 = R\,\frac{a}{2\left(b + \frac{c^2}{b}\right)}$$

Assume $a = \frac{77.5}{2} = 38.8$ $c = 12.5"$ $b = 37.0"$

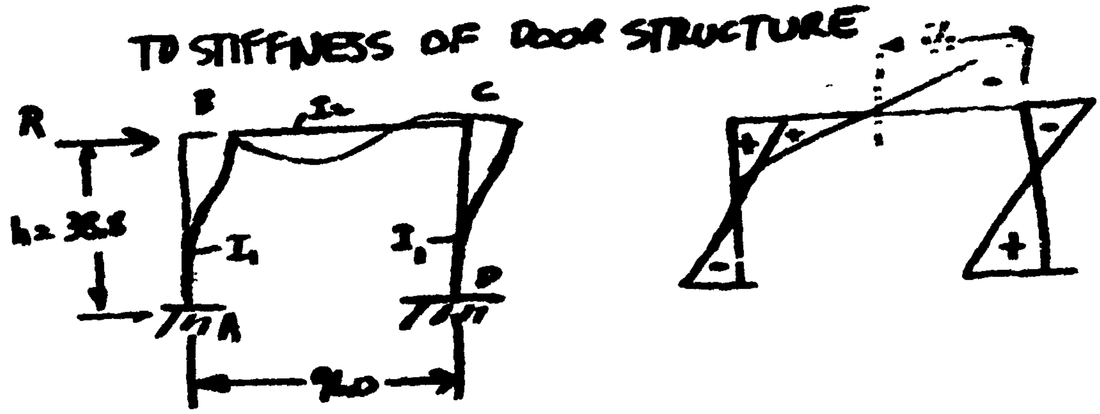
$$\therefore H_1 = R\,\frac{38.8}{2(\underbrace{37.0 + 4.2}_{41.2})} = R\,\frac{38.8}{82.4} = R(.47) \quad \text{use } H_1 = .5R$$

$$H_2 = H_1\left(\frac{12.5}{37.0}\right) = .34\,H_1 = .17\,R \quad \text{use } H_2 = .2R$$

TRICOM

DOOR

ASSUME DOOR POST BENDING STIFFNESS LARGE COMPARED TO STIFFNESS OF DOOR STRUCTURE



FRAME 41 KLEINLOGEL P. 197

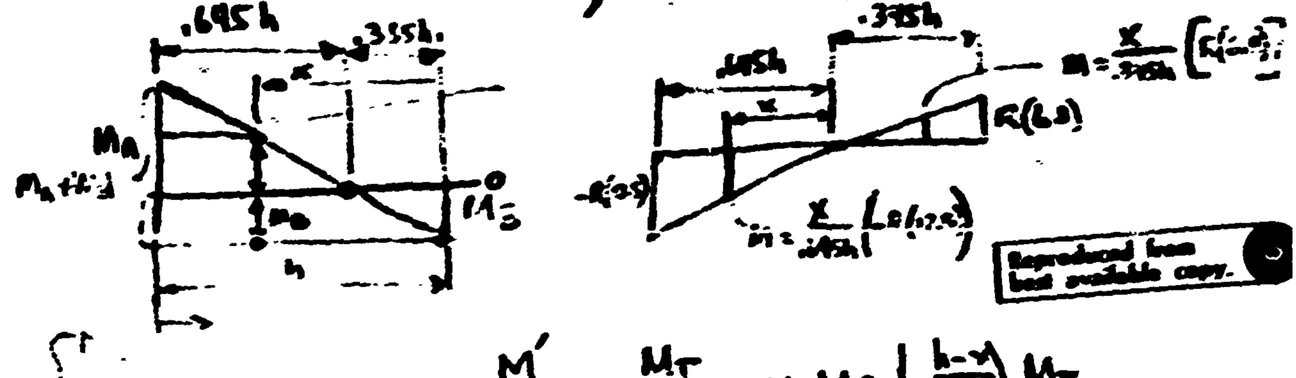
$h = 38.8$ $\quad l = 96.0$ $\quad I_2 = I_1 = 3.4 \text{ in}^4$

$k = \frac{I_2}{I_1}\left(\frac{h}{l}\right)$ $\quad N_1 = k + 2$ $\quad N_2 = 6k + 1$

$k = 1.0\left(\frac{38.8}{96.0}\right) = .405$ $\quad N_1 = 2.41$ $\quad N_2 = 3.43$

$M_A = -M_D = -\frac{Rh}{2}\left(\frac{3k+1}{N_2}\right) = -\frac{Rh}{2}\left(\frac{2.21}{3.43}\right) = -R(12.5)$

$M_B = -M_C = \frac{Rh}{2}\left(\frac{3k}{N_2}\right) = \frac{Rh}{2}\left(\frac{1.21}{3.43}\right) = R(6.84)$



$\frac{M'}{(h-x)} = \frac{M_T}{h} \quad \therefore M = \left(\frac{h-x}{h}\right) M_T$

$M = M' - M_B = \left(\frac{h-x}{h}\right)(\ldots) - M_B$

TRICON

DOOR

$$\delta_{M_1} = 2\int_0^a \frac{M m\,dx}{EI} = \frac{2}{EI}\int_0^{.645h} +R(12.5)\left(\frac{x}{.645h}\right)(12.5)\left(\frac{x}{.645h}\right)dx$$

$$= +\frac{2(12.5)^2 R}{EI(.645)^2 h^2}\left[\frac{x^3}{3}\right]_0^{.645h} = +\frac{2(12.5)^2(.645)^3 h^3 R}{3(.645)^2 h^2 EI} = +\frac{Rh}{EI}(67.2)$$

$$\delta_{M_2} = 2\int_0^b \frac{M m\,dx}{EI} = \frac{2}{EI}\int_0^{.355h} R(6.8)\left(\frac{x}{.355h}\right)(6.8)\left(\frac{x}{.355h}\right)dx$$

$$= \frac{2(6.8)^2 R}{EI(.355)^2 h^2}\left[\frac{x^3}{3}\right]_0^{.355h} = \frac{2(6.8)^2(.355)^3(h)^3 R}{3(.355)^2 h^2 EI} = +\frac{Rh}{EI}(10.6)$$

$$\delta_L = 2\int_0^c \frac{M m\,dx}{EI} = \frac{2}{EI}\int_0^{l/2} R(6.8)\left(\frac{x}{.5l}\right)(6.8)\left(\frac{x}{.5l}\right)dx$$

$$= \frac{2(6.8)^2 R}{EI(.5)^2 l^2}\left[\frac{x^3}{3}\right]_0^{l/2} = \frac{2(6.8)^2 R(.5)^3 l^3}{3EI(.5)^2 l^2} = \frac{Rl}{EI}(15.5)$$

$$\delta_T = \frac{R}{EI}\left[77.8\overset{38.7}{(h)} + 15.5\overset{96}{(l)}\right]$$

$$K_{DOOR} = \frac{R}{\delta} = \frac{EI}{[3020 + 14900]} = \frac{29(10)^3(3.4)}{17920} = 5.5(10)^3$$

$$K_{DOOR} = 5500\ \frac{LB}{IN} = \frac{R}{\delta}$$

TRICON

DOOR

FOR $\delta = 1.25''$

$R = 5500\,(1.25) = \underline{6870^{\#}}$

$M_{MAX} = R(12.5) = 86000$ IN-K

$f_{MAX} = \frac{86.0\,(2.0)}{3.4} = 50.6$ ksi $+ 1.88 = 52.5$

HINGE LOADS

$H_1 = .5\,R = 3435^{\#}$ (HORIZONTAL)

$H_V = .25\,R = 1720^{\#}$ (VERTICAL)

NO HINGE CONFIGURATION IS AVAILABLE FOR ANALYSIS.

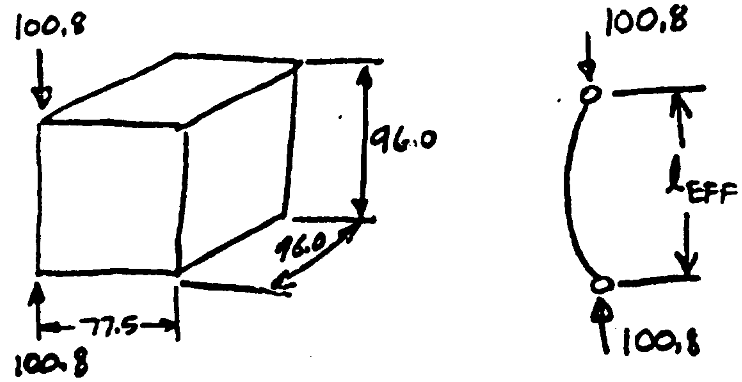
JOT 5-7-71

TRICON

LOAD SUMMARY

STACKING

DOOR SIDE POST



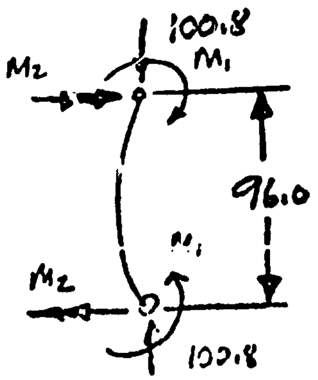
IF THE RELATIVE STIFFNESS BETWEEN THE DOOR HEADER AND LOWER SILL IS CONSTANT,

$$l_{eff} = .54\, l = .54(96) = 51.9'$$

AN INCREASE IN THE DOOR POST STIFFNESS OR A DECREASE IN THE STIFFNESS OF THE DOOR HEADER AND/OR LOWER SILL WILL INCREASE THE "EFFECTIVE" LENGTH.

$$P_{CR} = \frac{\pi^2 E I}{(l_{EFF})^2}$$

BLIND SIDE POST



$M_1 = P e_1$

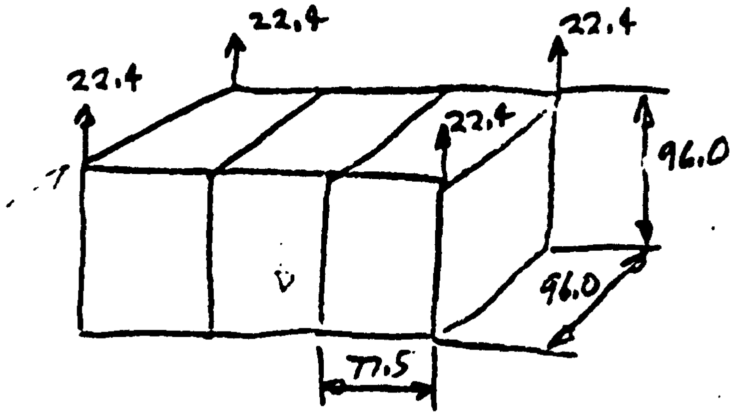
$M_2 = P e_2$

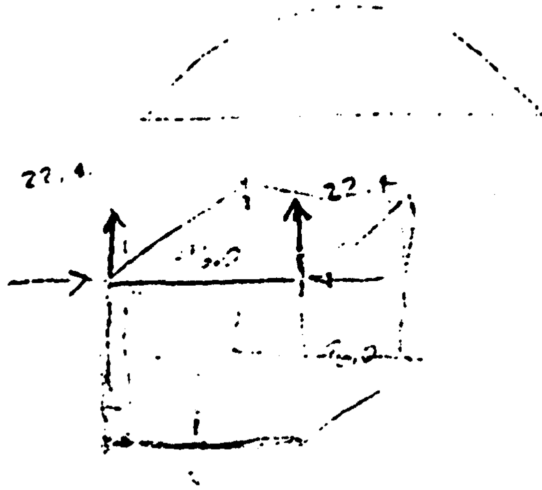
 5-6-71 -16

TRICON

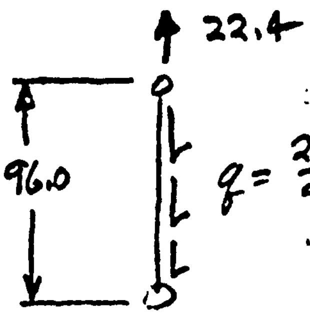
LOAD SUMMARY

LIFTING LOAD - TOP



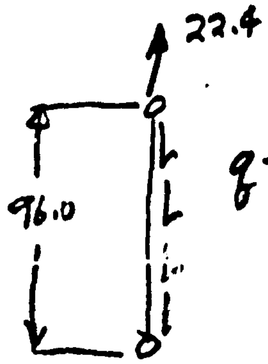


DOOR SIDE POST

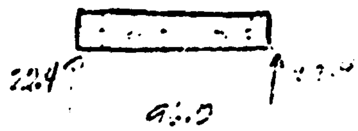


$q = \frac{22.4}{96} = .233\ ^{K}/_{IN}$

BLIND SIDE POST



$q = .233\ ^{K}/_{IN}$

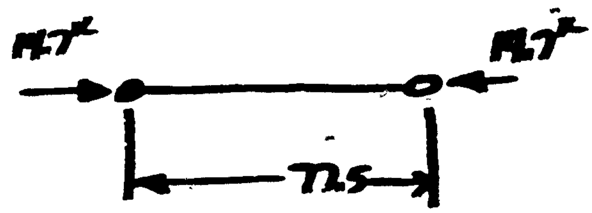


TRICON

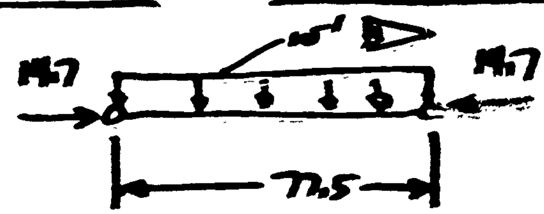
LOAD SUMMARY

LIFTING LOAD - TOP CONT'D

DOOR HEADER & BLIND SIDE TOP RAIL



DOOR LOWER SILL & BLIND SIDE LOWER RAIL



3 w' WILL DEPEND ON THE AMOUNT OF THE FLOOR LOAD TRANSFERRED BY THE FLOOR STRUCTURE (PLANKS) TO THE LOWER MEMBER. FROM THE ANALYSIS OF THE FLOOR LOADS, THIS LOAD IS ESTIMATED AS FOLLOWS:

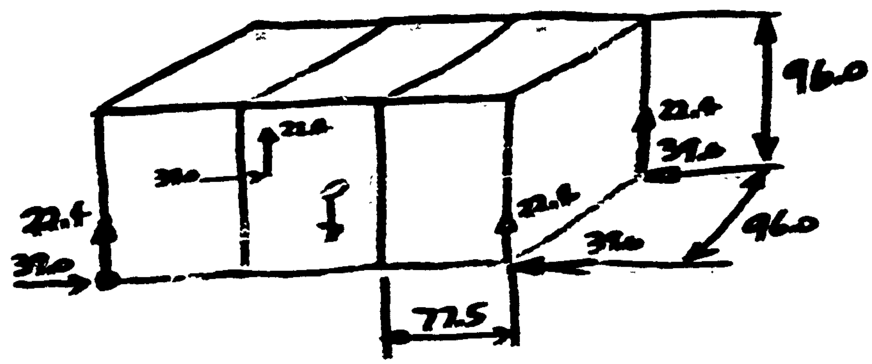
$$p \approx \left(\frac{89{,}600}{3}\right)\left(\frac{1}{6760}\right) = 4.41 \text{ psi} \quad \left(\begin{array}{l}\text{USE SAME AS FLOOR LOAD} \\ p = 4.44 \text{ psi}\end{array}\right)$$

$$w' = \left(\frac{23.4}{2}\right)(4.44) = 52.0 \text{ LB/IN}$$

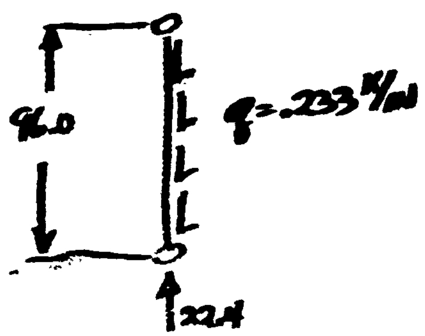
TRICON

LOAD SUMMARY

LIFTING LOAD—BOTTOM



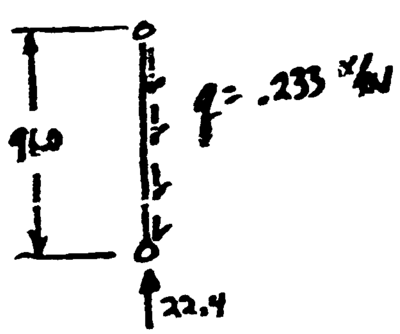
DOOR POST



$l_{EFF} = .732 l = .732(96) = 70.2''$

BLIND SIDE POST

$l_{EFF} = 70.2''$

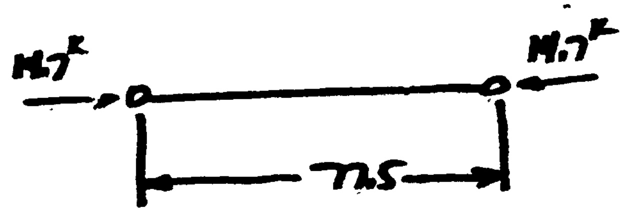


TRICON

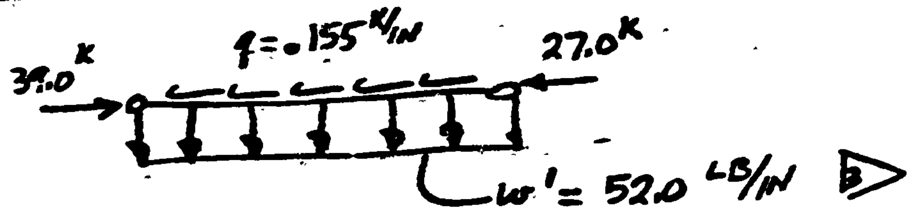
LOAD SUMMARY

LIFTING LOAD — BOTTOM CONT'D

DOOR HEADER & BLIND SIDE TOP RAIL



DOOR LOWER SILL & BLIND SIDE LOWER RAIL

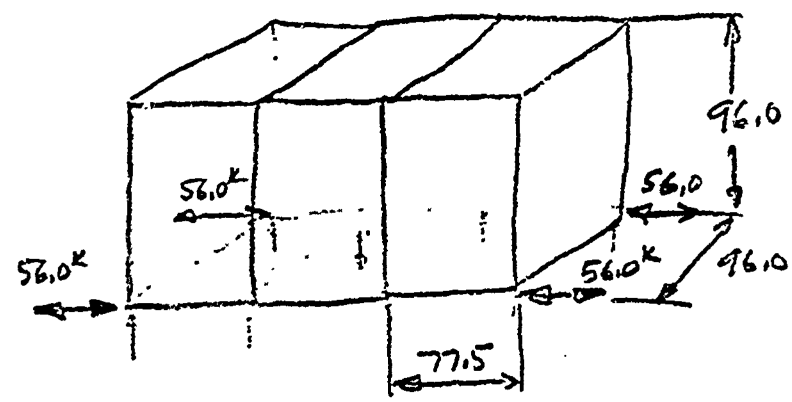


SEE 3 ON P. 52

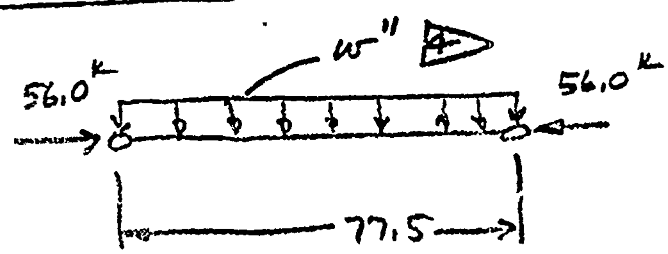
TRICON

LOAD SUMMARY

HORIZONTAL RESTRAINT



DOOR LOWER SILL & BLIND SIDE LOWER RAIL

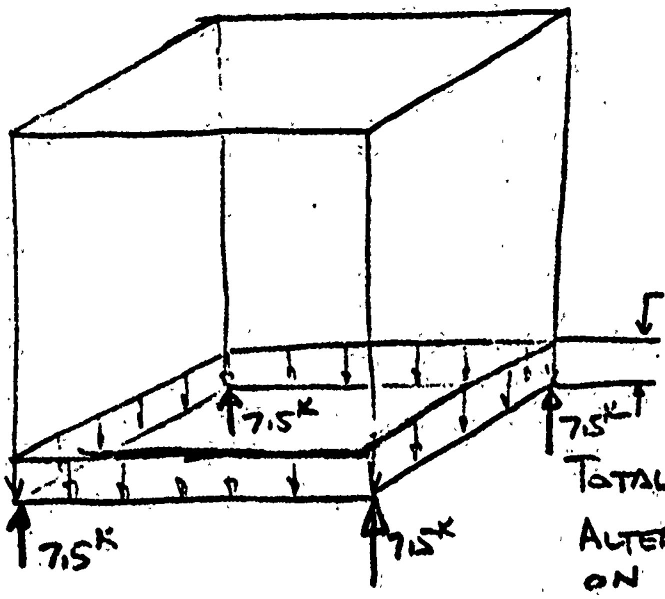


4 Assume $w'' = 52.0 \left(\frac{44.8}{89.6}\right) = 26.0$ LB/IN
(SEE P. 52)

TRICON

LOAD SUMMARY

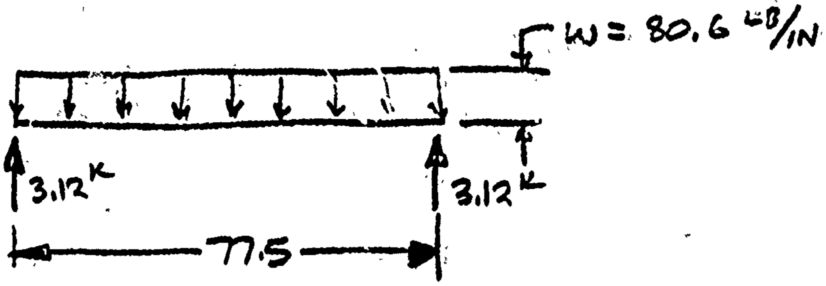
FLOOR LOADS



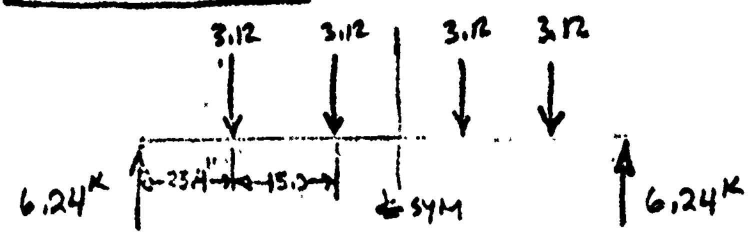
TOTAL LOAD = 30.0K

ALTERNATE LOAD = 6.0K ON 3.0" x 7 1/3"

FLOOR BEAM



LOWER SIDE RAIL



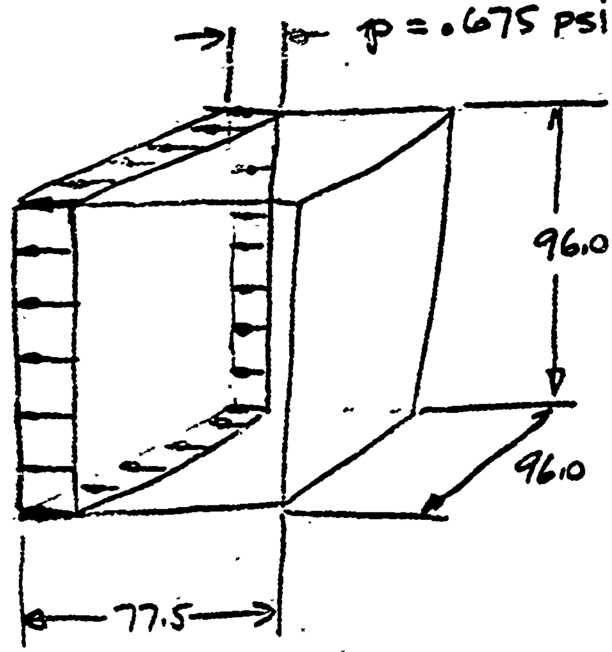
DIFFERENCE BETWEEN 6.24 AND 7.5K IS CARRIED TO CORNER FITTING BY DOOR SILL AND [illegible] SIDE LOWER RAIL

TRICON

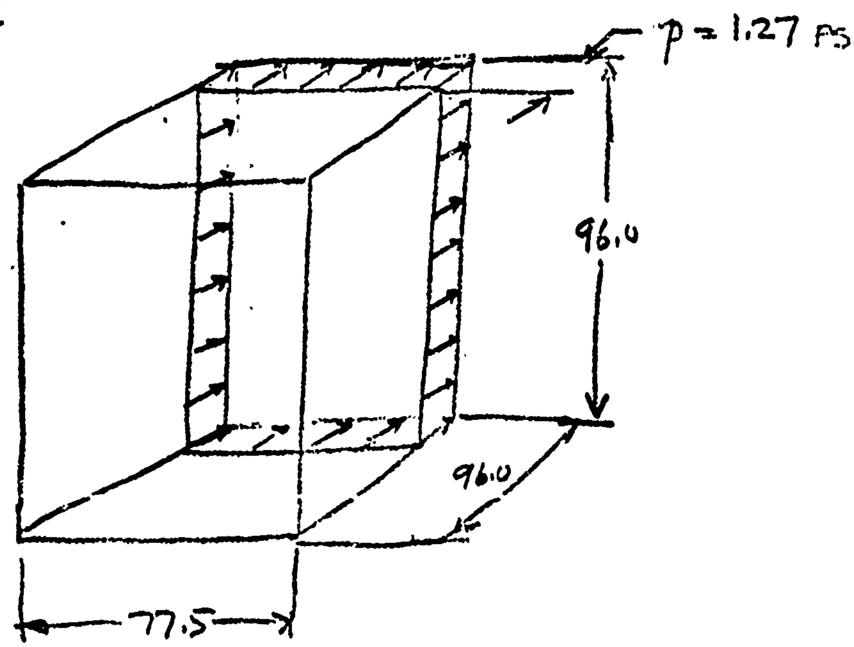
LOAD SUMMARY

WALL LOAD

SIDE WALL



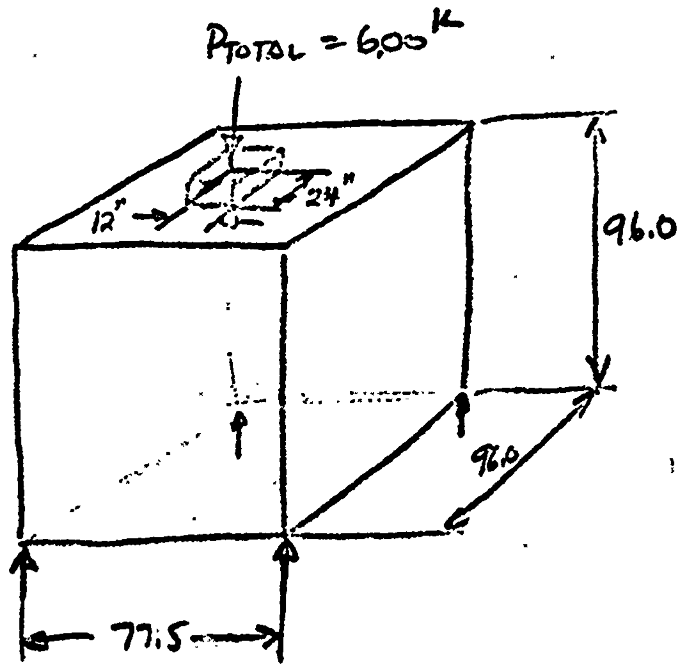
BLIND SIDE WALL



TRICON

LOAD SUMMARY

ROOF LOAD



SINCE ROOF WILL DISTRIBUTE RACKING LOAD ON DOOR SIDE IT WILL BE THE DESIGN CONDITION.

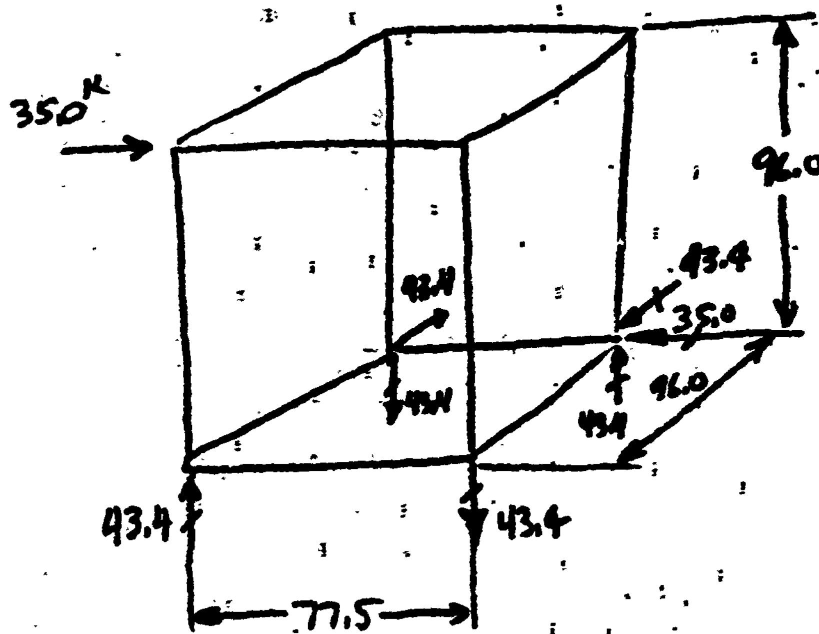
TRICON

LOAD SUMMARY

RACKING

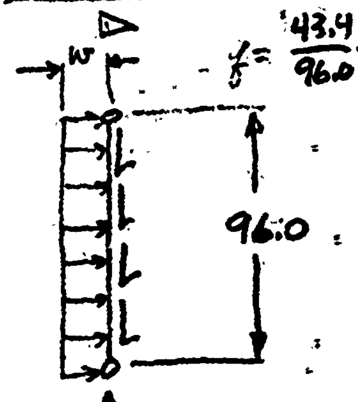
NOTE: ALL LOADS SHOWN ASSUME THAT THE DOOR STRUCTURE IS INCAPABLE OF DISTRIBUTING THE RACKING LOAD.
JGT 8-12-71

DOOR SIDE

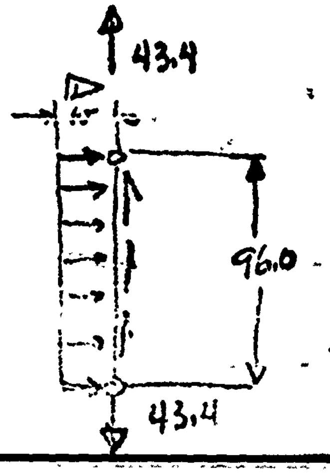


DOOR SIDE POST & BLIND SIDE POST [2]

$f = \frac{43.4}{96.0} = .450^{k}/_{IN}$



$l_{EFF} = .732\, l = 70.2''$



[1] THE MAGNITUDE OF w IS DEPENDENT UPON THE SIZE AND SPACING OF THE DIAGONALS. FOR 1/4 DIAM RODS SPACED AT 6.85" (ALONG THE HORIZONTAL) $w \approx 75$ LB/IN

[2] BLIND SIDE POST HAS AN ADDITIONAL w LOAD INTO (OR OUT OF) THE [illegible]

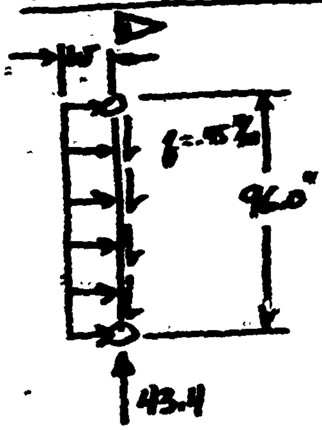
TRICON

LOAD SUMMARY

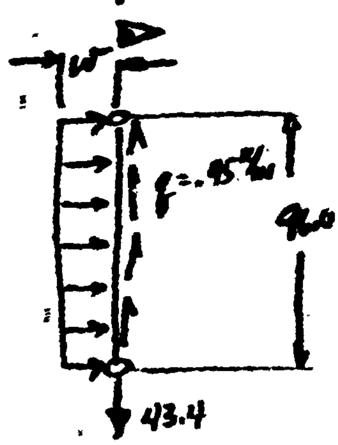
RACKING CONT'D

DOOR SIDE CONT'D

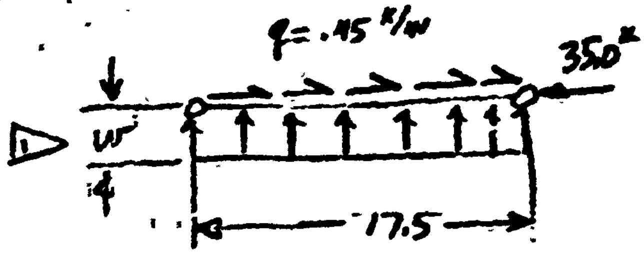
LOWER SIDE RAILS



$l_{EFF} = 70.2"$



BLIND SIDE LOWER RAIL & DOOR UPPER SILL



SEE P. FOR 1

JOT 5-6-71

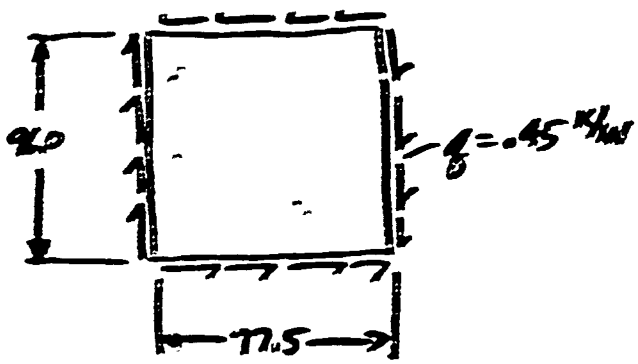
TRICON

LOAD SUMMARY

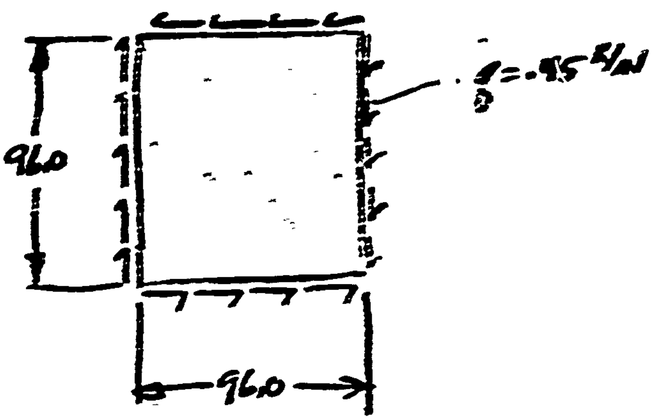
RACKING CONT'D

DOOR SIDE CONT'D

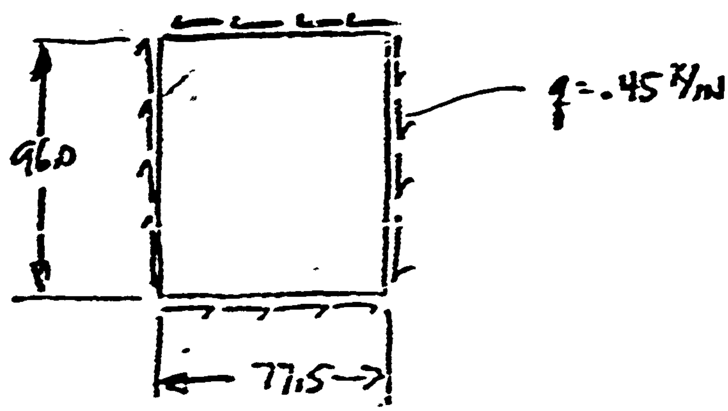
ROOF



SIDE WALL



BLIND SIDE WALL

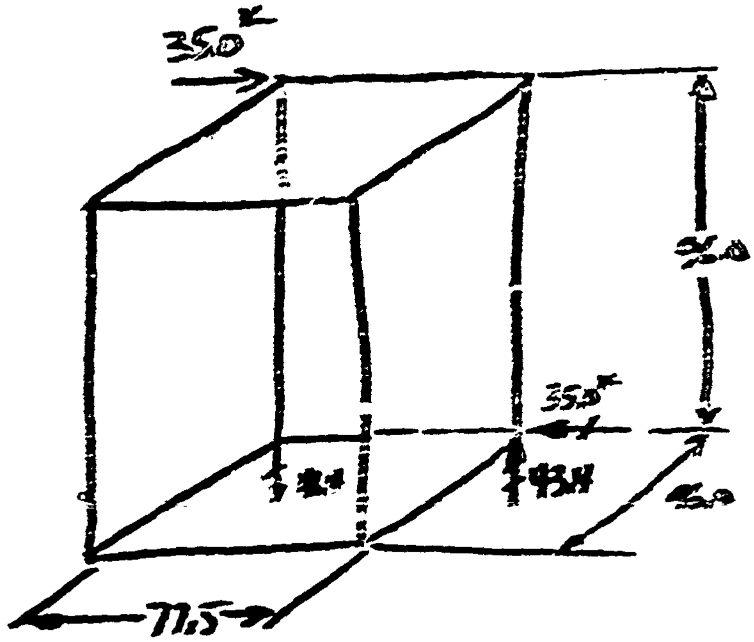


TRILON

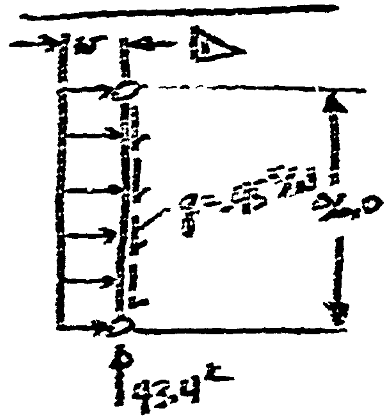
LOAD SUMMARY

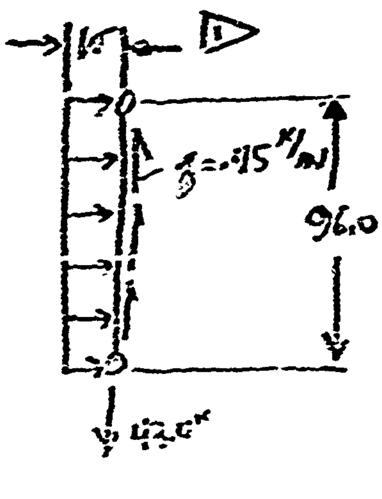
RACKING CONT'D

BLIND SIDE



BLIND SIDE POST





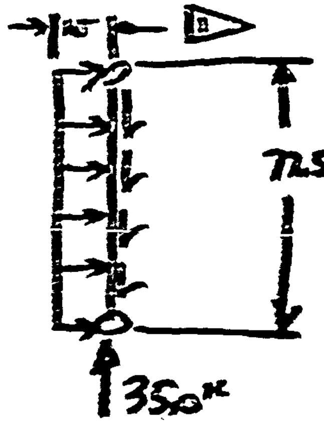
TRICON

LOAD SUMMARY

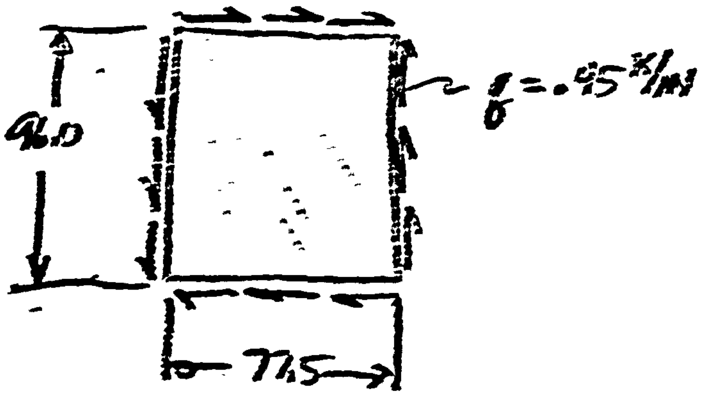
RACKING CONT'D

BLIND SIDE CONT'D

BLIND SIDE UPPER RAIL & BLIND SIDE LOWER RAIL



BLIND SIDE WALL

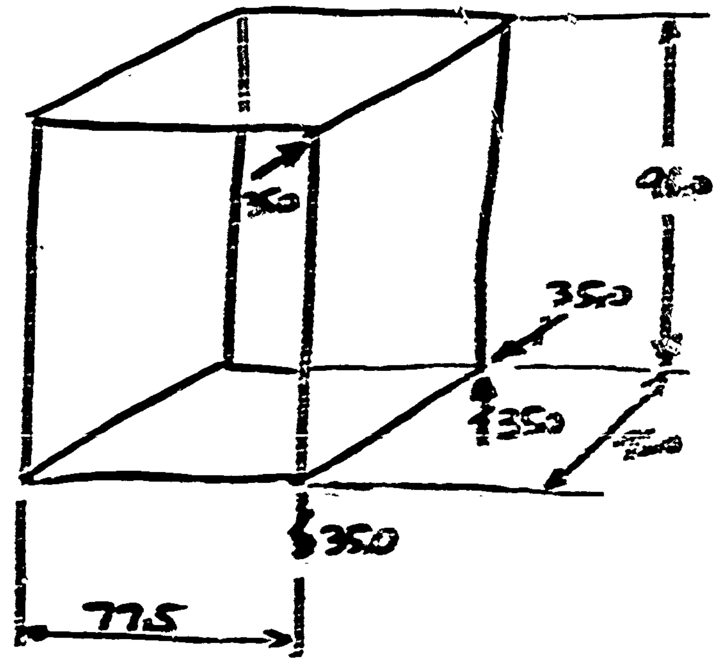


TRICON

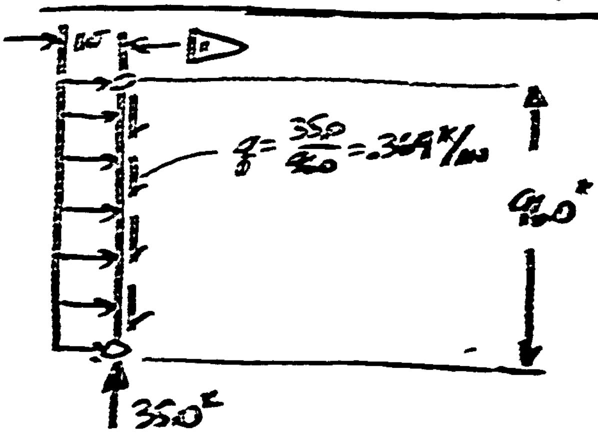
LOAD SUMMARY

RACKING LOAD'D

SIDE WALL



DOOR POST & BLIND SIDE POST



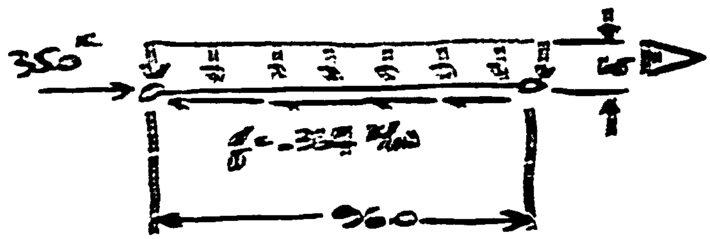
TRAILER

LOAD SUMMARY

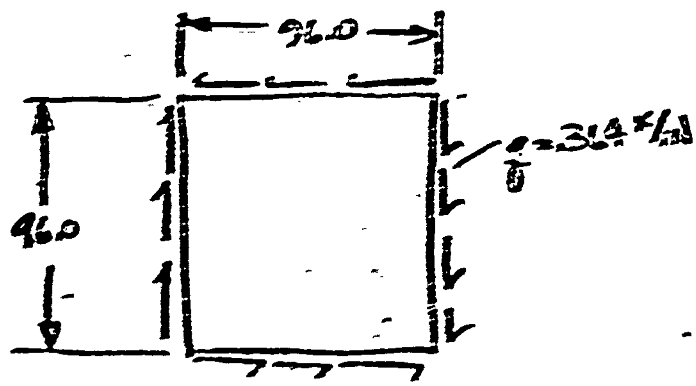
RACKOUT CONT'D

SIDE WALL CONT'D

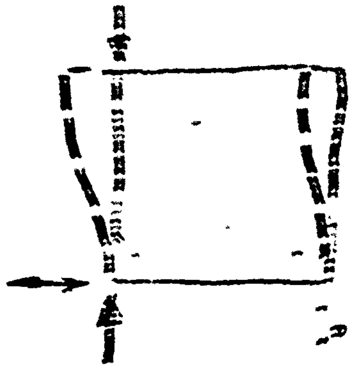
UPPER SIDE RAIL & LOWER SIDE RAIL



SIDE WALL



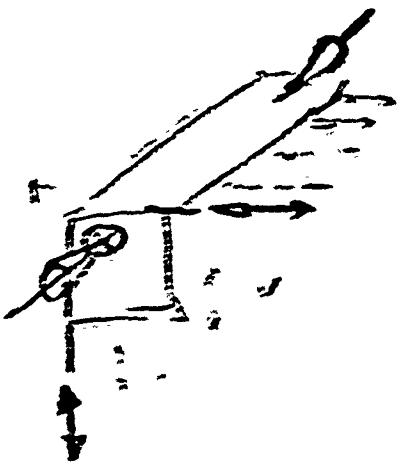
① Check the manner in which the corners are tied down for the "test" and "in service" applications



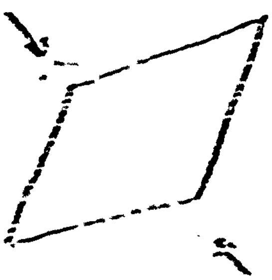
a) The amount of stiffness provided is a function of the manner in which the corners of the truss are tied down.

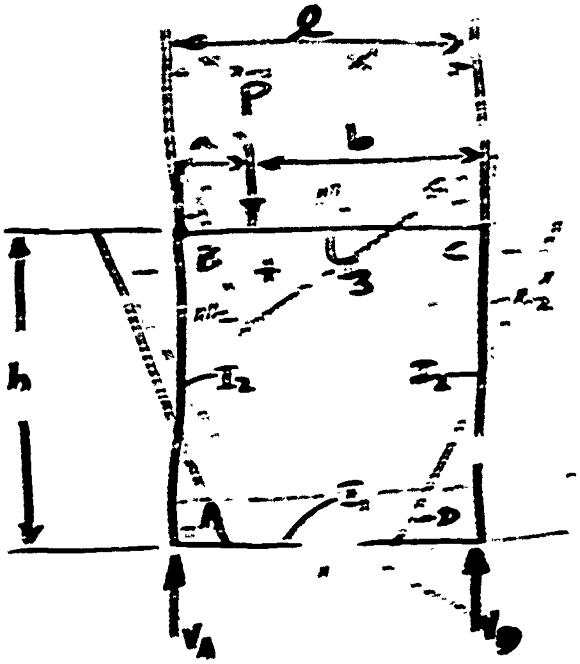
b) Racking Load Reactions (ARE ALL FOUR CORNERS TIED DOWN FOR RACKING LOADS ?)

②



Check sidewall influence on the stability of the structure.





KLEINLOGEL
FRAME 106/3
- KLEINLOGEL

LOAD FORMULAS p. 442 CASE 6

$\alpha = \frac{a}{l}$ $\beta = \frac{b}{l}$

$\mathcal{L} = Pa\beta(1+\beta)$

$\mathcal{R} = Pb\alpha(1+\alpha)$

$(\mathcal{L}+\mathcal{R}) = \frac{3Pab}{l}$

$(\mathcal{L}-\mathcal{R}) = P(b-a)\alpha\beta$

$S = P$ $\quad \mathfrak{S}_R = Pb$ $\quad \mathfrak{S}_L = Pa$

For region "a" $M_x^0 = P\beta x$

" " "b" $M_x^0 = P\alpha x'$

$$\left.\begin{matrix} M_A \\ M_D \end{matrix}\right\rangle \pm \frac{(\mathcal{L}+\mathcal{R})k_2}{2F_1} \mp \frac{(\mathcal{L}-\mathcal{R})}{2F_2} \qquad V_A = \frac{\mathfrak{S}_R}{l} \qquad V_D = \frac{\mathfrak{S}_L}{l}$$

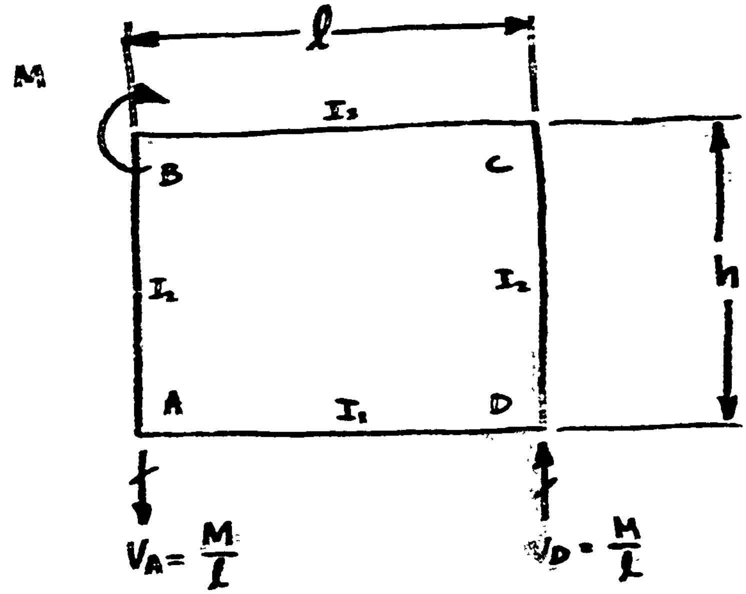
$$\left.\begin{matrix} M_B \\ M_C \end{matrix}\right\rangle - \frac{(\mathcal{L}+\mathcal{R})K_2}{2F_1} \mp \frac{(\mathcal{L}-\mathcal{R})}{2F_2} \qquad M_{x_2} = M_x^0 + \frac{x_2'}{l}M_B + \frac{x_2}{l}M_C$$

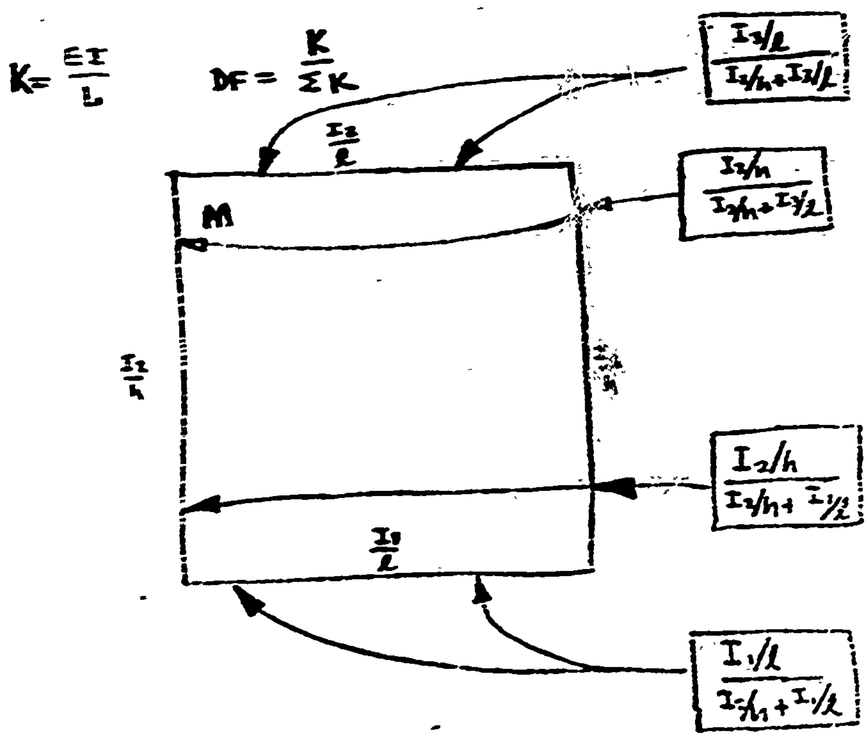
$$N_3 = -N_1 = \frac{M_A - M_B}{h} \qquad \left.\begin{matrix} N_2 = V_A \\ N_2' = V_D \end{matrix}\right\rangle \pm \frac{(\mathcal{L}-\mathcal{R})}{lF_2}$$

$k_1 = \frac{I_3}{I_1}$ $\quad k_2 = \frac{I_3}{I_2}\left(\frac{h}{l}\right)$ $\quad K_1 = 2k_2 + 3$

$K_2 = 3k_1 + 2k_2$ $\quad R_1 = 3k_2 + 1$ $\quad R_2 = k_1 + 3k_2$

$F_1 = K_1K_2 - (R_1)^2$ $\quad F_2 = 1 + k_1 + 6k_2$



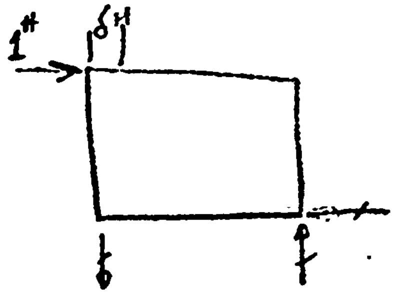


Assume $I_2 = 2.0$ $\quad h = 96.0$ $\quad \left(\frac{I}{L}\right)_1 = .021$

$I_1 = I_3 = 18.0$ $\quad \ell = 77.5$ $\quad \left(\frac{I}{L}\right)_2 = .232$ $\quad \Sigma K = .253$

$DF_1 = \frac{.021}{.253} = .083$ $\qquad DF_2 = \frac{.232}{.253} = .917$

1) Apply

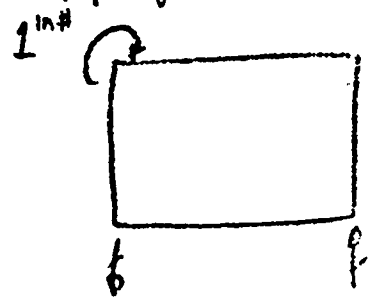


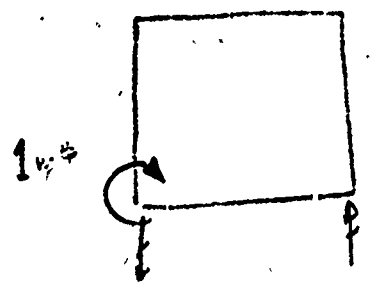
Account for shear panels

Check δ_H to see if sidesway is a problem

Probably not with shear panels ∴ Find spring rate.

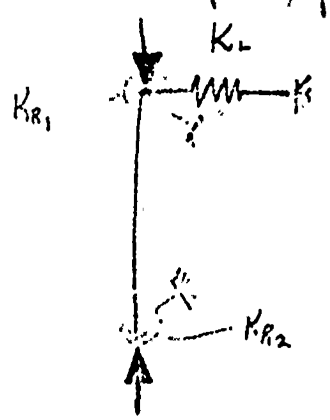
2) Apply

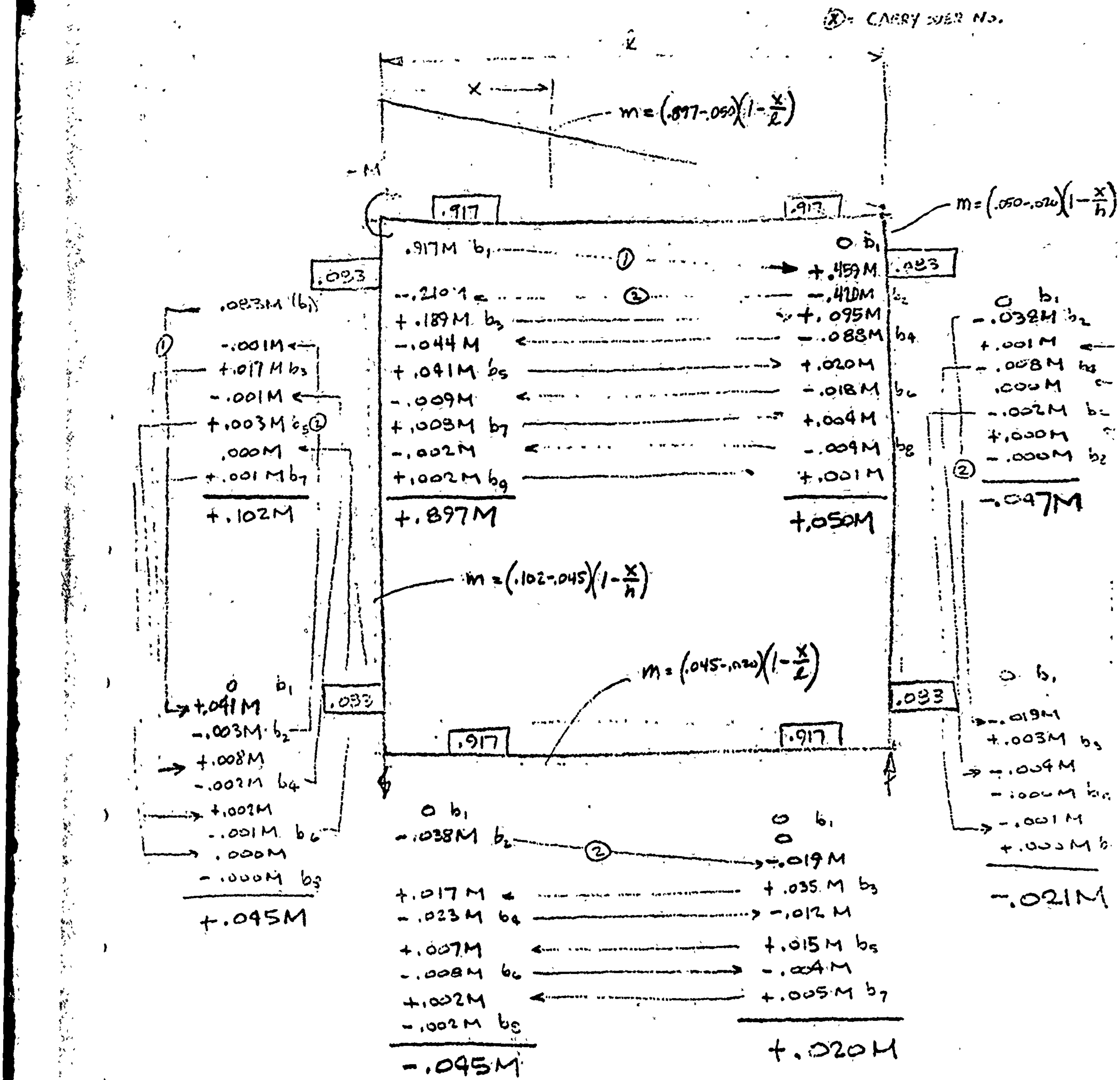




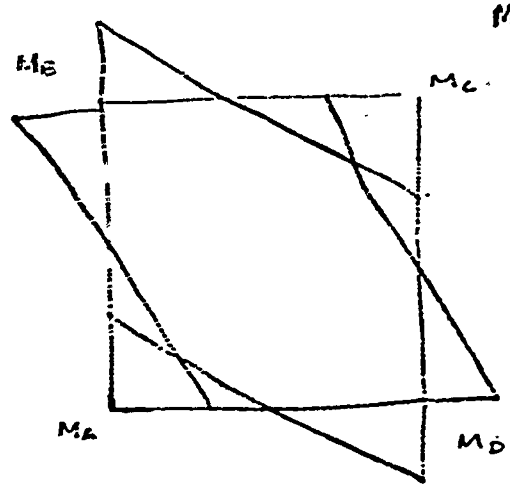
Find rotation @ B   Find rotation @ A

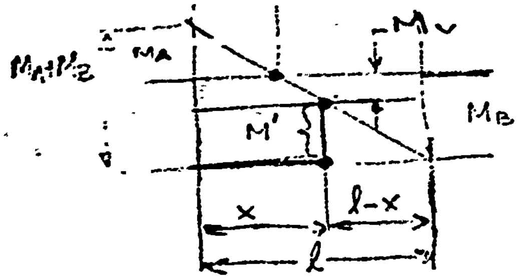
Therefore, for load P applied to top girder, column looks like this.





Ⓧ = CARRY OVER No.
ℓ
x
m = (.897 - .050)(1 - x/ℓ)
m = (.050 - .020)(1 - x/h)
.917
.917
.083
.083
.917M b1
①
0 b1
+.459M
-.210M
②
-.420M b2
+.189M b3
+.095M
-.044M
-.088M b4
+.041M b5
+.020M
-.009M
-.018M b6
+.009M b7
+.004M
-.002M
-.009M b8
+.002M b9
+.001M
+.897M
+.050M
.083M (b1)
-.001M
+.017M b3
-.001M
+.003M b5 ②
.000M
+.001M b7
+.102M
0 b1
-.038M b2
+.001M
-.008M b3
.000M
-.002M b5
+.000M
-.000M b7
②
-.047M
m = (.102 - .045)(1 - x/h)
m = (.045 - .020)(1 - x/ℓ)
0 b1
+.041M
-.003M b2
+.008M
-.002M b4
+.002M
-.001M b6
.000M
-.000M b8
+.045M
.083
.917
.917
.083
0 b1
-.019M
+.003M b3
-.004M
-.000M b5
-.001M
+.000M b7
-.021M
0 b1
-.038M b2
②
0 b1
0
-.019M
+.017M
+.035M b3
-.023M b4
-.012M
+.007M
+.015M b5
-.008M b6
-.004M
+.002M
+.005M b7
-.002M b8
-.045M
+.020M





$$\frac{M'}{l-x} = \frac{M_A+M_B}{l} \therefore M' = \left(1-\frac{x}{l}\right)(M_A+M_B)$$

$$M_x = M_A+M_B-M'-M_A = M_B-M'$$

$$= -M_B + \left(1-\frac{x}{l}\right)(M_A+M_B)$$

$$= -M_B + M_B\left(1-\frac{x}{l}\right) + M_A\left(1-\frac{x}{l}\right)$$

$$= -M_B\left(\frac{x}{l}\right) + M_A\left(1-\frac{x}{l}\right)$$

ASSUME $a = 5.0"$ $b = 70.0"$ $\therefore l = 75.0"$

$\alpha = \frac{5}{75} = .066$ $\beta = .934$

$(S+R) = \frac{3Pab}{l} = \frac{3(100)(5)(70)}{95} = 1100$

$(S-R) = 100(85.0)(.934)(.066) = 52.5$

$k_1 = \frac{I_3}{I_1} = 1.0$ $k_2 = \frac{I_3}{I_2}\left(\frac{h}{l}\right) = \frac{18.0}{2.0}\left(\frac{96}{77.5}\right) = 11.15$

$K_1 = 2k_2+3 = 2(11.15)+3 = 25.3$

$K_2 = 3k_1+2k_2 = 3+22.3 = 25.3$

$R_1 = 3k_2+1 = 34.45$

$R_2 = 1+3k_2 = 34.45$

$F_1 = 25.3(25.3) - (11.15)^2 = 515$

$F_2 = 1+k_1+6(k_2) = 2+6(11.15) = 68.9$

$$M_A = \frac{1420(11.15)}{2(515)} - \frac{42.6}{2(68.9)} = 15.40 - .31 = \cancel{15.09}\ \text{IN}\cdot\text{K}$$

11.1 – 11.5

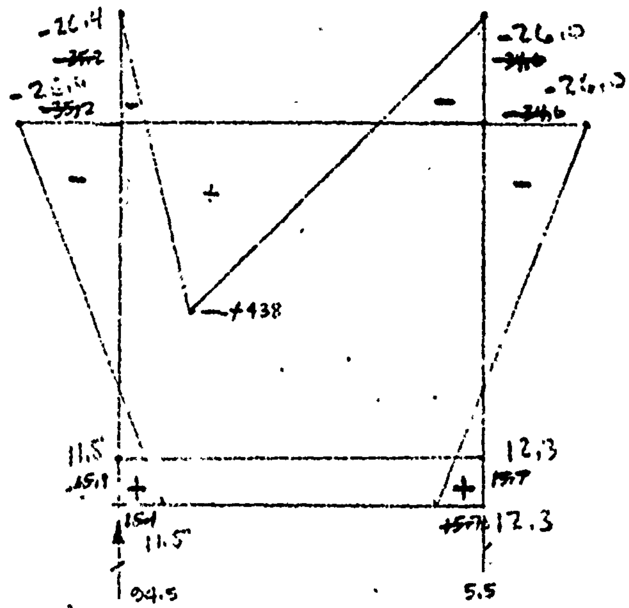
$$M_D = 15.40 + .31 = \overset{12.3}{15.71}\ \text{IN}\cdot\text{K}$$

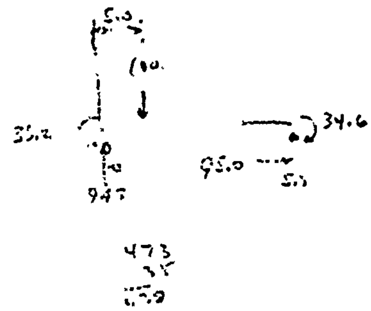
$$M_B = -\frac{1420(25.3)}{1030} - .31 = -34.9 - .3 = \cancel{-35.2}\ \overset{-26.4}{}\ \text{IN}\cdot\text{K}$$

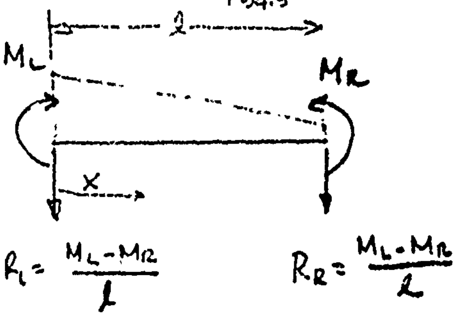
$$M_C = -34.9 + .3 = \cancel{-34.6}\ \text{IN}\cdot\text{K}$$

26.4 –26.0

$$V_A = 100\left(\frac{70}{75}\right) = 93.5 \qquad V_D = 5.5$$

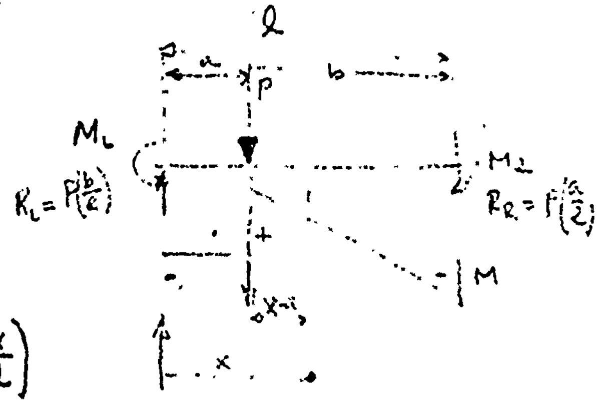






$$R_L = \frac{M_L - M_R}{l} \qquad R_R = \frac{M_L - M_R}{l}$$

$$M_x = M_L - R_L(x) = M_L - (M_L - M_R)\left(\frac{x}{l}\right)$$



$0 \to a \quad M = -M_L + P\left(\frac{b}{l}\right)x$

$a \to l \quad M = -M_L + P\left(\frac{b}{l}\right)x - P(x - a)$

$$\theta = \int \frac{Mm\,dx}{EI}$$

$$\theta = \frac{1}{EI}\int_0^h \frac{\left[\underset{11.5}{15.1} - \left(\underset{11.5}{15.1} + \underset{26.0}{35.2}\left(\frac{x}{h}\right)\right)\right]\left[\left(.102 - .045\right)\left(1 - \frac{x}{h}\right)\right]dx}{}$$

$$+ \frac{1}{EI}\int_0^h \left[\underset{12.3}{15.7} - \left(\underset{12.3}{15.7} + \underset{26.0}{34.6}\left(\frac{x}{h}\right)\right)\right]\left[\left(.050 - .020\right)\left(1 - \frac{x}{h}\right)\right]dx$$

$$+ \frac{1}{EI}\int_0^l \left[\underset{11.5}{15.1} - \left(\underset{11.5}{15.1} - \underset{12.3}{15.7}\right)\left(\frac{x}{l}\right)\right]\left[\left(.045 - .020\right)\left(1 - \frac{x}{l}\right)\right]dx$$

$$+ \frac{1}{EI}\int_0^a \left[\underset{26.4}{-35.2} + \underset{93.5}{94.5}(x)\right]\left[\left(\overset{.147}{.897} - .050\right)\left(1 - \frac{x}{l}\right)\right]dx$$

$$+ \frac{1}{EI}\int_a^l \left[\underset{26.4}{-35.2} + \underset{93.5}{94.5}(x) - 100\left(x - a\right)\right]\left[\left(.897 - .050\right)\left(1 - \frac{x}{l}\right)\right]dx$$

$$\theta = \frac{1}{EI}\left[\int_0^h \left[-\overset{2.29}{3.02}\left(\frac{x}{h}\right) + \overset{2.29}{3.02}\left(\frac{x}{h}\right)^2\right]dx + \int_0^l \left[.393\left(\frac{x}{l}\right) - .393\left(\frac{x}{l}\right)^2\right]dx\right.$$

$$+ \int_0^a \left[-\overset{22.4}{29.8} + \overset{79.2}{80.0}x + \overset{22.4}{29.8}\left(\frac{x}{l}\right) - \overset{79.2}{80.8}\left(\frac{x^2}{l}\right)\right]dx$$

$$\left. + \int_a^l \left[-\overset{22.4}{29.8} + \overset{22.4}{29.8}\left(\frac{x}{l}\right) - \overset{5.53}{4.65}(x) - \overset{5.50}{4.65}\left(\frac{x^2}{l}\right) + 84.7(a) - 84.7a\left(\frac{x}{l}\right)\right]\right]$$

$$\theta = \frac{1}{EI_h}\left[\frac{2.29(x)^2}{2h} + \frac{2.29(x)^3}{3h^2}\right]_0^h + \frac{1}{EI_L}\left\{\left[\frac{.268(x)^2}{2\ell} - \frac{.268(x)^3}{3\ell^2}\right]_0^\ell\right.$$

$$+ \left[-22.4 + \frac{79.2(x)^2}{2} + \frac{22.4(x)^2}{2\ell} - \frac{79.2(x)^3}{3\ell}\right]_0^a$$

$$+ \left[-22.4 + \frac{22.4(x)^2}{2\ell} - \frac{5.50(x)^2}{2} - \frac{5.50(x)^3}{3\ell} + 84.7(a) - \frac{84.7(a)(x)^2}{2\ell}\right.$$

$$\theta = \frac{1}{EI_h}\left[-1.15(h) + .76(h)\right] + \frac{1}{EI_L}\left\{\left[.134(\ell) - .089(\ell)\right] + \right.$$

$$\left[-22.4 + 39.6(a)^2 + 11.2\left(\frac{a^2}{\ell}\right) - 26.4\left(\frac{a^3}{\ell}\right)\right] +$$

$$\left[-22.4 + 11.2\ell - 11.2\left(\frac{a^2}{\ell}\right) - 2.75(\ell)^2 + 2.75(a)^3 - 1.83(\ell)^2 + 1.83\left(\frac{a^3}{\ell}\right)\right.$$

$$\left.\left. + 84.7(a) - 42.4(a\ell) + 42.4\left(\frac{a^3}{\ell}\right)\right]\right\}$$

$$\theta = \frac{1}{EI_h}\left[-.39(h)\right] + \frac{1}{EI_L}\left[11.25(\ell) - 4.58(\ell)^2 + 17.8\left(\frac{a^3}{\ell}\right) + 84.7(a)\right.$$

$$\left. + 39.6(a)^2 + 2.75(a)^3 - 42.4(a\ell) - 44.8\right]$$

$$EI_h = 29.0(10)^6(2.0) = 58.0(10)^6$$

$$EI_L = 29.0(10)^6(18.0) = 521(10)^6$$

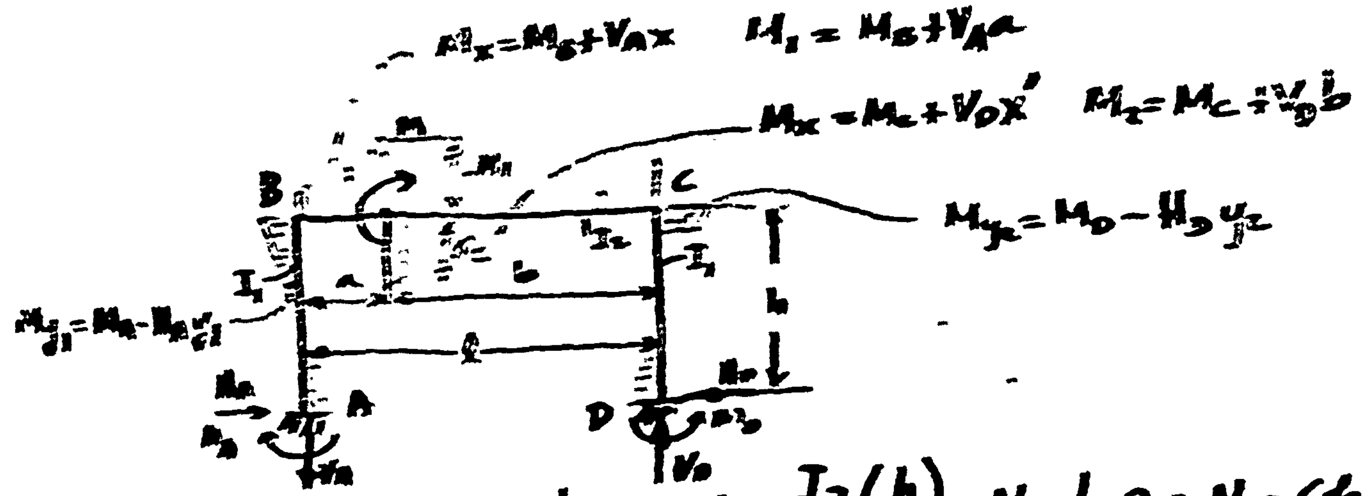
$h = 95 \qquad \ell = 75 \qquad a = 5.0 \qquad a^2 = 25 \qquad a^3 = 125$

$\ell^2 = 5630$

$$\theta = \frac{-37.1}{58.0(10)^6} + \frac{1}{521(10)^6}\left[\overset{844}{11.25(75)} \overset{-25800}{- 4.58(5630)} \overset{+29.7}{+ 17.8\left(\frac{125}{75}\right)} \overset{+424}{84.7(5)} \overset{+990}{+ 39.6(25)} \overset{+344}{+ 2.75(125)} \overset{-15900}{- 42.4(5)(75)} \overset{-35}{- 44.8}\right]$$

$$\theta = -.64(10)^{-6} - \overset{13.8}{\frac{7213}{521}}(10)^{-6} = -14.4(10)^{-6} \text{ RAD}$$

KLEINLOGEL FRAME 41



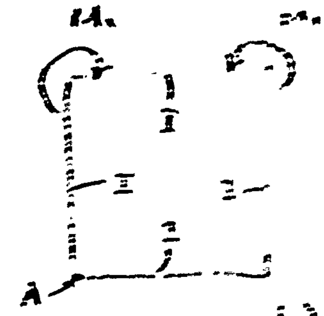
$\alpha = \frac{a}{\ell} \quad \beta = \frac{b}{\ell} \quad k = \frac{I_2}{I_1}\left(\frac{h}{\ell}\right);\ N_1 = k+2;\ N_2 = 6k+1$

$$\left.\begin{matrix} M_A \\ M_D \end{matrix}\right\rangle = M\left[\pm \frac{\beta-\alpha}{2N_1} \mp \frac{1-6\alpha\beta}{2N_2}\right]$$

$$\left.\begin{matrix} M_B \\ M_C \end{matrix}\right\rangle = M\left[-\frac{\beta-\alpha}{N_1} \mp \frac{1-6\alpha\beta}{2N_2}\right]$$

$$H_A = H_D = \frac{3M(\beta-\alpha)}{2hN_1}$$

$$V_D = -V_A = \frac{6M(k+\alpha\beta)}{\ell N_2}$$



$M_A = M_1 \left(\frac{ab}{a+b}\right)$

$a = 0 \quad \therefore \quad \alpha = 0 \cdot \quad \beta = 1$

$$\left.\begin{matrix} M_A \\ M_D \end{matrix}\right\rangle = M\left[\frac{1}{2N_1} \mp \frac{1}{2N_2}\right]$$

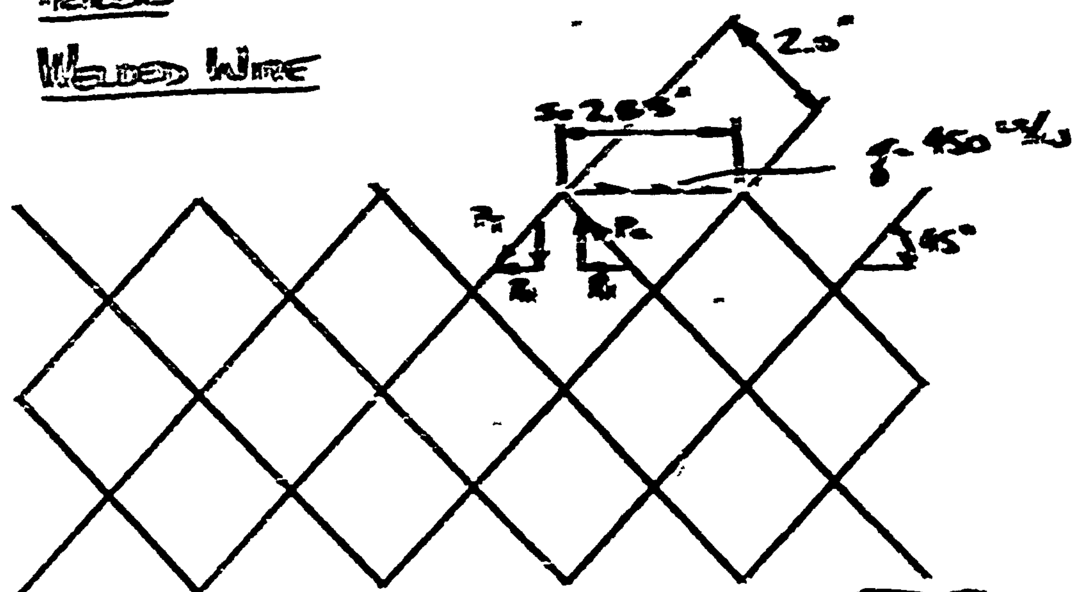
$$\left.\begin{matrix} M_B \\ M_C \end{matrix}\right\rangle = M\left[-\frac{1}{N_1} \mp \frac{1}{2N_2}\right]$$

$$H_A = H_D = \frac{3M}{2hN_1}$$

$$V_D = -V_A = \frac{6Mk}{\ell N_2}$$

TRICON

WELDED WIRE



NOTE: S = SPACING PARALLEL WITH EDGE MEMBER

ASSUME COMPRESSION STABILITY

$$2P_H = qS \quad \therefore P_H = \frac{qS}{2}$$

$$P_T = -P_c = 1.414\,P_H = .707\,qS$$

Assume $q = 450 \quad S = 2.83 \quad \therefore P_T = -P_c = 900^{\#}$

$$P_{CR} = 900^{\#} = \frac{\pi^2 E I}{l^2} = \frac{9.86(29)(10)^6 I}{4}$$

$$I = \frac{4(900)(10)^{-6}}{9.86(29)} = .0000126$$

$$I = \frac{\pi D^4}{64} = .0491\,D^4 \quad \therefore D^4 = \frac{.0000126}{.0491} = 2.56(10)^{-4}$$

$$D = .1265 \text{ IN} \qquad A = .785\,D^2 = .785(1.6)(10)^{-2} = .0126 \text{ in}^2$$

$$f_{CR} = \frac{900}{.0126} = 71{,}400 \text{ psi}$$

TRICOM

WELDED WIRE

$\rho = .5R = .25(D) = .25(.1265) = .0316$

$\frac{l}{\rho} = \frac{2.0}{.0316} = 63.3$

$F_{CR} = \frac{\pi^2 E}{\left(\frac{l}{\rho}\right)^2} = \frac{9.86(29)(10)^6}{(63.3)^2} = 71,500 \text{ psi}$

ASSUME STEEL WIRE GAUGE NO. 10

DIAM = .135

$\rho = .25(.135) = .0338$

$\frac{l}{\rho} = \frac{2.0}{.0338} = 59.1$

$F_{CR} = \frac{\pi^2 E}{\left(\frac{l}{\rho}\right)^2} = \frac{9.86(29)(10)^6}{(59.1)^2} = 81,800 \text{ psi}$

CHECK — USE 75,000 PSI F_{TU} COLDRAWN WIRE

$\frac{F}{E} = \frac{\pi^2}{\left(\frac{l}{\rho}\right)^2} = \frac{9.86}{(3500)} = .00282$

CHECK WITH TANGENT MODULUS CURVE FOR 4340M

$F_{TY} = 132$ $F_{TU} = 150$ $\frac{F_{TY}}{F_{TU}} = .88$

ASTM 82-62 T SHOWS THE FOLLOWING FOR 10 GAGE AND UP

$F_{TY} = 65,000$ $F_{TU} = 75,000$ $\frac{F_{TY}}{F_{TU}} = .866$

JOT 2-11-71

TRICON

WELDED WIRE

ASSUME $E_T = 23.5(10)^6$ psi

$$F_{CR} = \frac{9.96\,(23.5)(10)^6}{3500} = 66{,}400 \text{ psi}$$

THIS SEEMS HIGH, FOR EXAMPLE 4130 STEEL WITH

$\frac{\ell}{\rho} = 60$ HAS $F_{CR} = 58.0$ ksi $\quad F_{TY} = 75.0$

ASSUME $F_{CR} = \frac{65.0}{75.0}(58.0) = 50.3$ ksi

$$f = \frac{900}{.0143} = 63.0 \text{ ksi}$$

TRY #9 GAGE; DIAM = .148, A = .0172

$$\frac{\ell}{\rho} = \frac{2.0}{.037} = 54.0$$

FOR 4130 $\frac{\ell}{\rho} = 54.0 \quad F_{CR} = 60.0$

ASSUME $F_{CR} = \frac{65.0}{75.0}(60.0) = 52.0$ ksi

$$f = \frac{900}{.0172} = 52.3 \text{ ksi}$$

$$MS = \frac{52.0}{52.3} - 1 = -.05$$

NOTE: #9 WELDED WIRE ON 2.0" MESH IS VERY CLOSE
SINCE NO DATA IS AVAILABLE ON THE T[illegible]
MODULUS CHARACTERISTICS, IT SEEMS A[illegible]
TO RECOMMEND USING #8 GAGE (DIAM=
.162, AREA = .0206)

TRICON

WELDED WIRE

CHECK #8 GAGE WIRE ($D = .1620$ $A = .0206$)

$$\frac{\ell}{\rho} = \frac{2.0}{.0405} = 49.5$$

FOR 4130 WITH $\frac{\ell}{\rho} = 50.0$ $F_{CR} = 62.0$

ASSUME $F_{CR} = \frac{65}{75}(62.0) = 53.8$ KSI

$$f = \frac{900}{.0206} = 43.6$$

$$MS = \frac{53.8}{43.6} - 1 = \boxed{+.23}$$ (#8 GAGE WIRE 2.0" MESH)

USE SIMILAR CALCULATIONS TO CHECK 1.0" MESH

$q = 450$ LB/IN $S = 1.0(1.414) = 1.414$"

$P = .707\,qS = (1.414)\,450(.707) = 450$ #

TRY #14 GAGE (DIAM = .080 AREA = .005026)

$$\frac{\ell}{\rho} = \frac{1.0}{.02} = 50.0$$

FOR 4130 WITH $\frac{\ell}{\rho} = 5.0$ $F_{CR} = 62.0$

ASSUME $F_{CR} = \frac{65.0}{75.0}(62.0) = 53.8$

$$f = \frac{450}{.00503} = 89.5 \text{ KSI}$$

TRICON

WELDED WIRE

TRY #12 GAGE (DIAM = .1055 A = .00874)

$$\frac{\ell}{\rho} = \frac{1.0}{.0264} = 37.9$$

FOR 4130 WITH $\frac{\ell}{\rho} = 38.0$ $F_{CR} = 68.0$

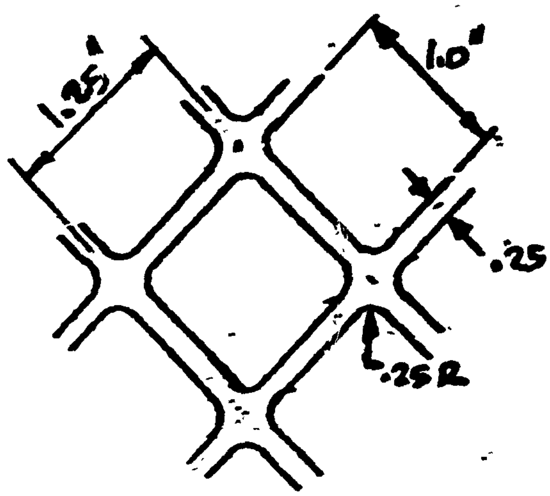
ASSUME $F_{CR} = \frac{65.}{75.}(68.0) = 59.0$ KSI

$$f = \frac{450}{.00874} = 51.5 \text{ KSI}$$

$$M.S. = \frac{59.0}{51.5} - 1 = \underline{\underline{+.15}} \quad \left(\begin{array}{c}\#12 \text{ GAGE} \\ 1.0'' \text{ MESH}\end{array}\right)$$

TRICON

PUNCHED PANEL

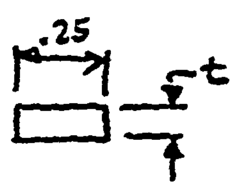


	GAGE	t
.10	12	.104
.112	11	.119
.125	10	.13[illegible]
.1[illegible]	8	.16[illegible]
.160	7	.18[illegible]
.180		
.190		
.200		

$s = 1.414(1.25) = 1.77''$

$q = 450$ LB/IN

$P_c = .707\,q\,s = .707(1.77)(450) = 563$ LB



$I_{MIN} = \dfrac{.25(t)^3}{12} = .0208\,t^3$

$A = .25\,t \qquad \rho_{MIN} = \sqrt{\dfrac{.0208t^3}{.25t}} = \sqrt{.0833t^2} = .289t$

TRY USING ASTM - A441 (3/16 t OVER)
- A375 (3/16 t UNDER)

TRY 12 GAGE $t = .1046$; $\rho = .0302$ $A = .0261$

$\dfrac{l}{\rho} = \dfrac{1.25}{.0302} = 41.4$

FOR 4130 $\dfrac{l}{\rho} = 42.0$ $F_{CR} = 67.0$

TRICON

PUNCHED PANEL

ASSUME $F_{CR} = \frac{50}{75}(67.0) = 44.6$ KSI

$f = \frac{563}{.0261} = 21.6$ KSI

MORE EFFICIENT TO DECREASE WIDTH.

TRY $w = .20$ $\quad I = .0166\,t^3$ $\quad A = .20\,t$

$\rho = \left(\frac{.0166\,t^2}{.20}\right)^{1/2} = \left(.0831\,t^2\right)^{1/2} = .289\,t$

TRY $t = .1046$ $\quad \rho = .0302$ $\quad A = .0209$

ASSUME $F_{CR} = 44.6$ KSI

$f = \frac{563}{.0209}\left(\frac{1.2}{1.25}\right) = 25.8$ KSI

TRY $w = .15$, $t = .1046$ $\quad \rho = .0302$ $\quad A = .0157$

ASSUME $F_{CR} = 44.6$ KSI

$f = \frac{563}{.0157}\left(\frac{1.15}{1.25}\right) = 33.0$ KSI

FOR $f = F_{CR}$ $\quad \frac{563}{.1046(w)} = 44{,}600$ OR $W = \frac{563}{44600(.1046)} = .121$

TRY $w = .125$

$A = .125(.1046) = .0130$ $\quad$ FOR $\frac{\ell}{\rho} = \frac{1.125}{.0302} = 37.3$ $\quad F_{CR} = F_{cy} = 50$

$f = \frac{563}{.130}\left(\frac{1.125}{1.25}\right) = 39.0$ KSI

$$M.S. = \frac{50.0}{39.0} - 1 = \underline{\underline{+.28}}$$

(1.0" SQUARE PUNCH
W = .125 $\quad$ t = .1045
ASTM-A375)

COULD PROBABLY ITERATE AND GET W DOWN ($\approx$ .10 INCH)
BUT WITH THE DATA AVAILABLE, THIS IS GOOD ENOUGH.

TRICON

PUNCHED PANEL

ROUGH SIZE WITH $F_{cy} = 150.$ KSI STEEL (IE 4130)

ASSUME SQUARE

$I = \frac{t^4}{12}$ $A = t^2$ $\rho = \left(\frac{t^2}{12}\right)^{1/2} = .288\,t$

P_c: .707 f (1.414) l = f l

t	l	ρ	l/ρ	F_{CR}	P_c	A	f	MS
.06	1.06	.0173	61.3	79.0	476	.0036	132.5	-.41
.07	1.07	.0202	53.0	92.0	481	.0049	98.4	-.06
.08	1.08	.0230	47.0	100.	486	.0064	76.0	+.31
.09	1.09	.0259	42.1	106.	490	.0081	60.6	+.79

ASSUME $t = .075$

[1.0" SQUARE PUNCH
$w = t = .075$
$F_{cy} = 150.$ KSI (4130)]

TRICON

PUNCHED PANEL

CHECK WITH 2.0" SQUARE PUNCH

$S = 2.83"$

$P_T = .707\, q\, S = .707\,(450)(2.83) = 900^{\#}$

TRY $w = .15$ $t = .164$ $A = .0246$ $\rho = .289(.15) = .0434$

$f = \frac{900}{.0246} = 35.6$ ksi

FOR 4130 @ $\frac{l}{\rho} = \frac{2.15}{.0434} = 49.6$ $F_{CR} = 62.0$ ksi

ASSUME $F_{CR} = \frac{50.}{75.}(62) = 41.4$ ksi

$M.S. = \frac{41.4}{35.6} - 1 = \underline{+.16}$

(2.0" SQUARE PUNCH
w = .15 t = .164
ASTM A-375)

ROUGH SIZE USING 150. ksi YIELD STEEL

t	l	ρ	l/ρ	F_{CR}	P_c	A	f	MS
.10	2.10	.0289	72.6	59.0	945	.010	94.5	-.375
.11	2.11	.0318	66.5	70.0	950	.0121	78.5	-.110
.12	2.12	.0346	61.3	79.0	954	.0144	66.1	+.19
.13	2.13	.0376	56.6	90.0	959	.0169	56.6	+.59
.14	2.14	.0405	52.9	100.	963	.0196	49.1	+1.04

ASSUME $t = .115$

[2.0" SQUARE PUNCH
$w = t = .115$
$F_{cy} = 150$ ksi (4130)]

TRICON

WALL LOADS

PUNCHED PANELS – SIDE WALLS

$\bar{t} = .0233$ (1.0" SQUARE PUNCH W=.125 t=.1046)

$n_1 = .318$ $n_2 = .356$ $q = p = .675$

$$W_{MAX} = 28.6\left[\frac{60.8}{29(10)^6(.0233)}\right]^{1/3} = 28.6\left[90.0(10)^{-6}\right]^{1/3}$$

.675 (10)²

$$= 28.6(4.49)(10)^{-2} = 1.28''$$

60.8 ?

$$S_{MAX} = .356\left[29(10)^6\left[\frac{.675(90)}{.0233}\right]^2\right]^{1/3} = .356\left[29(6.8)(10)^{12}\right]^{1/3}$$

2,610 197

$$= .356\,[5.81](10)^4 = 20{,}700 \text{ PSI}$$

PUNCHED PANELS – BLIND SIDE WALL

$n_1 = .269$ $n_2 = .364$ $p = q = 1.27$

$$W_{MAX} = 24.2\left[90.\left(\frac{1.27}{.675}\right)(10)^{-6}\right]^{1/3} = 24.2\left[169(10)^{-6}\right]^{1/3} = 24.2(5.52)($$

$$= 1.34''$$

$$S_{MAX} = .364\left[29(10)^6\left[\frac{1.27(90)}{.0233}\right]^2\right]^{1/3} = .364\left[29(24.1)(10)^{12}\right]^{1/3}$$

4900 24.1 698

$$= .364(8.88)(10)^4 = 32{,}400 \text{ PSI}$$

FOR $F_{TY} = 50.0$

$$M.S. = \frac{50.0}{32.4} - 1 = \underline{+.54}$$

TRICON

PROPOSED PANELS – SUMMARY

WELDED WIRE

MESH SIZE	WIRE GAGE (DIAM)
2.0"	#8 (.162)
1.0"	#12 (.1055)

PUNCHED PANEL

PUNCH SIZE	SHT. GAGE (THICK)	WIDTH	MAT'L
2.0"	#8 (.1644)	.15	ASTM A375
1.0"	#12 (.1046)	.125	ASTM A375

NOTE: THE ABOVE SIZES ARE REQUIRED FOR $q = 450$ LB/IN. THIS IS CONSERVATIVE SINCE THE STRUCTURE HAS SECONDARY LOAD PATHS THAT WILL REDUCE THE MAXIMUM APPLIED SHEAR FLOWS. THESE PANELS ARE SIMILAR TO THE PREVIOUSLY ANALYZED PANELS IN THE REACTIONS AND DEFORMATIONS THAT RESULT FROM OUT-OF-PLANE LOADS, AS SUMMARIZED BELOW

	BLIND SIDE	R.H OR L.H. SIDE
MAXIMUM STRESS	33,000 PSI	21,000 PSI
MAXIMUM DEFLECTION	1.35"	1.30"

IF THESE PANELS ARE ATTACHED SIMILARLY TO THE PLYWOOD PANELS WITH RESPECT TO THE ECCENTRICITIES AT THE EDGE MEMBERS, THE INDUCED LOADS AND STRESSES IN THE EDGE MEMBER WILL BE SIMILAR.

JOT 8-16-71

TRICON

WALL LOADS

PLYWOOD PANELS – SIDE WALLS

$$W_{max} = n_1 a \left(\frac{qa}{Et}\right)^{1/3}$$

$$S_{max} = n_2 \left[E\left(\frac{qa}{t}\right)^2\right]^{1/3}$$

$P_{TOTAL} = 5460^{LBS}$

$n_1 = .318$ SEE P (31) $\quad n_2 = .356 \quad t = .595$ SEE P. 10 $\quad q = p = .675\ ^{LB}/_{IN}$ SEE P. (31)

$$W_{MAX} = .318(90)\left[\frac{\overset{60.3}{.675(90)}}{\underset{.655}{1.1(10)^6(.595)}}\right]^{1/3} = 28.6\left[92.8(10)^{-6}\right]^{1/3}$$

1.46" FOR 7784 LBS

$$= 28.6(\overset{5.10}{4.54})(10)^{-2} = 1.30'' \quad \left(\text{TEST SHOWED FOR 7784 LS } 1.50''/1.32\right.$$

$$S_{MAX} = .356\left[1.1(10)^6\left[\frac{\overset{60.8}{.675(90)}}{\underset{102}{.595}}\right]^2\right]^{1/3} = .356\left[11.45(10)^9\right]^{1/3}$$

10400

$$= .356(2.26)(10)^3 = 805 \text{ psi}$$

PLYWOOD PANELS – BLIND SIDE $\quad P_{TOTAL} = 8100^{LB}$

Assume $a/b = \frac{90}{71} = 1.27 \quad p = 1.27$ psi (SEE P. 32A)

$$n_1 = .318 - \frac{.27}{.50}(.090) = .269$$

$$n_2 = .356 + \frac{.27}{.50}(.014) = .364$$

$$\therefore W_{MAX} = 28.6\left(\frac{.269}{.318}\right)\left[92.8\left(\frac{1.27}{.675}\right)(10)^{-6}\right]^{1/3} = 24.2\left[174.5(10)^{-6}\right]^{1/3}$$

$$W_{MAX} = 24.2(5.58)(10)^{-2} = 1.35'' \quad (\text{TEST SHOWED } 1.75'')$$

TRICON

WALL LOADS

PLYWOOD PANELS - BLIND SIDE

$$S_{max} = .364\left[1.1(10)^6\left[\frac{1.27(90)}{.595}\right]^2\right]^{1/3} = .364\left[40.5(10)^9\right]^{1/3}$$

$$= .364(3.44)(10)^3 = 1250 \text{ psi}$$

JCT 8-17-71

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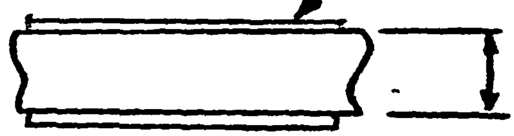
TRICON

W. SIDE PANEL



FIBERGLASS:

Assume $\rho = .06\ ^{LB}/_{IN^3} = .06(16) = .96\ ^{oz}/_{in^3}$

$1\ sq\ yd = 1296\ sq.in \therefore W = \frac{18\ oz\ yd^2}{1296\ in^2\ yd^2} = .0139\ ^{oz}/_{in}$

$t = \frac{.0139\ in^3\ oz}{.96\ oz\ in^2} = .0145\ in$ (STD PLY THICKNESS FOR 182 FABRIC = .014)

Assume 182 FABRIC – BAC 5426 DM 81-D2 24.331

	0° & 90°	45°	
F_T =	36,000	17,000	
F_c =	30,000	15,000	
F_s =	8,500	21,000	PSI
E =	2,600,000	2,100,000	
G =	1,000,000	1,000,000	

JT 9-11-71 11

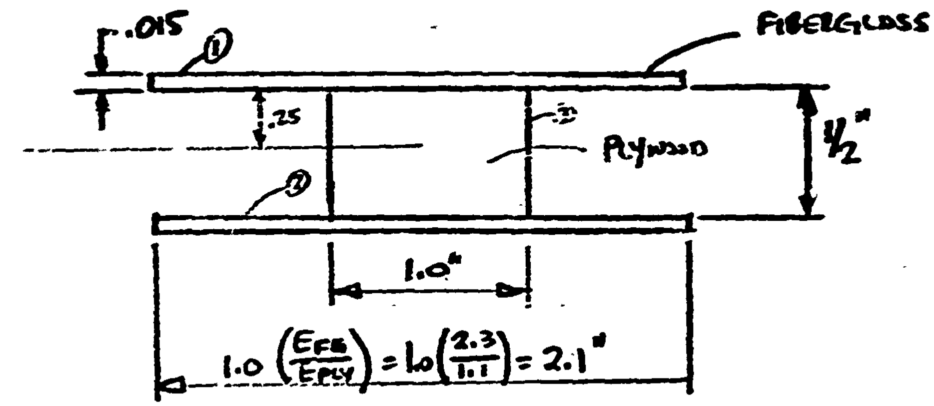
TRICON

W. SIDE PANEL

PLYWOOD – GROUP I C-D EXTERIOR ANC-18

	0°	90°
F_T	7970	7130
F_C	2520	2280
F_S	1800	
E	1,117,000	1,010,000

CALCULATE EQUIVALENT ρ BASED ON PLYWOOD MODULUS



ELEM	A	y	Ay	Ay²	I
1	.0315	.32	.0104	.0032	0
2	.0315	-.32	-.0104	.0032	0
3	.5000	0	0	0	.0104
	.5630			.0064	.0104

I = .0168

$$\rho_{EQUIV} = \left(\frac{.0168}{.563}\right)^{1/2} = (.0298)^{1/2} = .172$$

$$\text{FOR SOLID SECTION, } \rho = \left(\frac{\frac{bh^3}{12}}{bh}\right)^{1/2} = \left(\frac{h^2}{12}\right)^{1/2} = .289\,h = .289$$

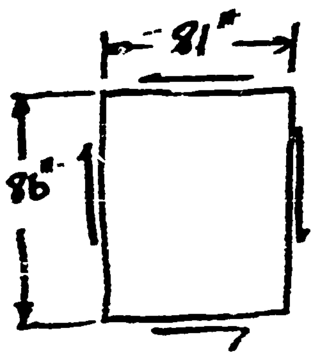
TRICON

W. SIDE PANEL

THEREFORE, THE EQUIVALENT SECTION THICKNESS BASED ON EQUAL ρ WILL BE

$$\rho = \rho_{EQUIV} \quad \therefore \quad .289t = .172$$

$$t = .595''$$



ASSUME % = 1.0

FOR SIMPLE SUPPORTS $K = 8.0$
" FIXED " $K = 13.0$

$$F_{s_{CR}} = KE\left(\frac{t}{b}\right)^2$$

SIMPLE SUPPORTS

$$F_{SCR} = 8.0(1.1)(10)^6\left(\frac{.595}{81.0}\right)^2 = 8.0(1.1)(54.0) = 475 \text{ PSI}$$

$$q_{CRIT} = 475(.595) = 283 \text{ LB/IN}$$

FIXED SUPPORTS

$$F_{SCR} = 475\left(\frac{13.0}{8.0}\right) = 770 \text{ PSI}$$

$$q_{CRIT} = 770(.595) = 459 \text{ LB/IN}$$

50% FIXITY

ASSUME $q_{CRIT} = \frac{742}{2} = 370$ LB/IN

FOR .50" PLYWOOD PANEL ONLY:
SIMPLE SUPPORTS: $F_{SCR} = 8.0(1.1)(38.2) = 336$ PSI $\quad q_{CRIT} = 168$ LB/IN
FIXED SUPPORTS: $F_{SCR} = 336(13.0/8.0) = 546$ PSI $\quad q_{CRIT} = 274$ LB/IN
50% FIXITY: $q_{CRIT} = 221$ LB/IN

TRICON

W. SIDE PANELS

DISTRIBUTE SHEAR LOADS ACCORDING TO TRANSFORMED AREAS.

$$q_{FIBERGLASS} = \frac{.063}{.563} q = .112\, q$$

$$q_{PLYWOOD} = \frac{.500}{.563} q = .888\, q$$

$F_s = q/t$

SIMPLE SUPPORTS ; $q = 283$

$q_{FG} = 31.7$ $F_s = 1060$ PSI

$q_{PL} = 251.$ $F_s = 502$ PSI

FIXED SUPPORTS ; $q = 459$

$q_{FG} = 51.4$ $F_s = 1710$ PSI

$q_{PL} = 407.$ $F_s = 814$ PSI

50% FIXITY ; $q = 370$

$q_{FG} = 41.4$ $F_s = 1380$ PSI

$q_{PL} = 329.$ $F_s = 658$ PSI

FOR FIBERGLASS $F_{SU} = 8500$ PSI (MINIMUM)

FOR PLYWOOD $F_{SU} = 1800$ PSI (MAXIMUM)

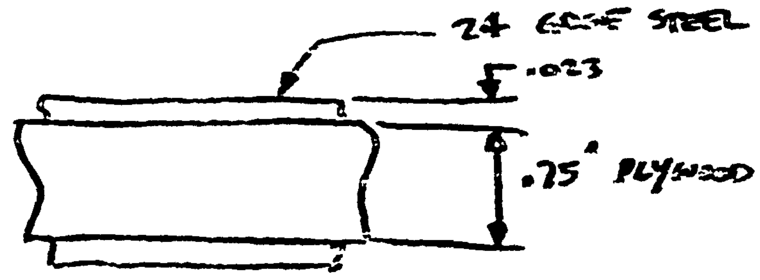
SIDE PANELS STABILITY CRITICAL

FIBERGLASS INCREASES F_{SCR} BY $\frac{283}{168} - 1 = 68\%$

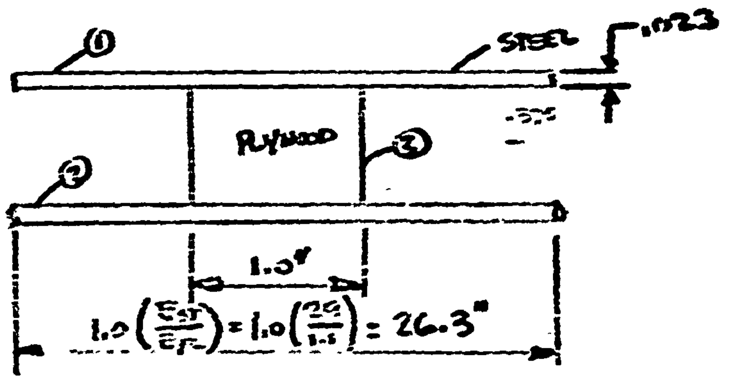
DOT 8-12-71

TRIKON

W. DOOR PANEL



CALCULATE EQUIVALENT ρ BASED ON PLYWOOD MODULUS



ELEM	A	y	Ay	Ay^2	I_o	A_{ACTUAL}
1	.605	.386	.234	.0901	0	.023
2	.605	-.386	-.234	.0901	0	.023
3	.750	0	0	0	.0352	.750
	1.960			.1802	.0352	.796

$I = .2154$

$$\rho_{EQUIV.} = \left(\frac{.2154}{.796}\right)^{1/2} = (.270)^{1/2} = .52$$

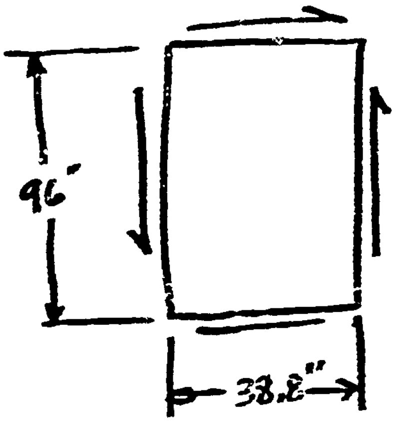
FOR SOLID SECTION $\rho = .289\,t$

$$\therefore \quad t_{EQUIV.} = \frac{.520}{.289} = 1.80"$$

JOT 8-12-71

TRICON

W. DOOR PANEL



ASSUME $\frac{a}{b} = \frac{96}{38.8} = 2.48$

FOR SIMPLE SUPPORTS $K = 5.5$

" FIXED SUPPORTS $K = 8.9$

$F_{SCR} = KE\left(\frac{t}{b}\right)^2$

SIMPLE SUPPORTS

$F_{SCR} = 5.5(1.1)(10)^6\left(\frac{1.80}{38.8}\right)^2 = 5.5(1.1)(2150) = 13000$ PSI

$q_{CRIT} = 13000(.796) = 10,350$ LB/IN

FIXED SUPPORTS

$F_{SCR} = 13000\left(\frac{8.9}{5.5}\right) = 21,000$ PSI

$q_{CRIT} = 21,000(.796) = 16,800$ LB/IN

50% FIXITY

ASSUME $q_{CRIT} = \frac{10,350 + 16,800}{2} = 13,500$ LB/IN

FOR .75" PLYWOOD PANEL ONLY,

SIMPLE SUPPORTS: $F_{SCR} = 5.5(1.1)(10)^6\left(\frac{.75}{38.8}\right)^2 = 2260$ PSI $\quad q_{CRIT} = 1700$ LB/IN

FIXED SUPPORTS: $F_{SCR} = 2260\left(\frac{8.9}{5.5}\right) = 3660$ PSI $\quad q_{CRIT} = 2740$ LB/IN

50% FIXITY: $q_{CRIT} = 2220$ LB/IN

TRIKON

W. DOOR PANEL

SHEAR LOADS DISTRIBUTED ACCORDING TO TRANSFORMED AREAS.

$$q_{STEEL} = \frac{1.21}{1.96}(q) = .617\, q \qquad F_s = \frac{q}{t}$$

$$q_{PLYWOOD} = \frac{.75}{1.96}(q) = .383\, q \qquad F_s = q/t$$

SIMPLE SUPPORTS ; $q = 10{,}400$

$q_{STEEL} = .617\,(10{,}400) = 6{,}420$ LB/IN $\quad F_s = 139.0$

$q_{PLYWOOD} = .383\,(10{,}400) = 3{,}980$ LB/IN $\quad F_s = 5.31$

FIXED SUPPORTS ; $q = 16{,}800$

$q_{STEEL} = .617\,(16{,}800) = 10{,}380$ LB/IN $\quad F_s = 226.$

$q_{PLYWOOD} = .383\,(16{,}800) = 6{,}420$ LB/IN $\quad F_s = 8.56$

50% FIXITY $\quad q = 13{,}500$

$q_{STEEL} = .617\,(13{,}500) = 8{,}340$ LB/IN $\quad F_s = 181.$

$q_{PLYWOOD} = .383\,(13{,}500) = 5{,}160$ LB/IN $\quad F_s = 6.90$

APPEARS THAT THE STEEL FACE SHEETS WILL YIELD IN SHEAR AT A LOAD LEVEL BELOW THE CRITICAL STABILITY LOAD. IF $F_{SU} = .70\,F_{TY}$ AND A LOW STRENGTH STEEL IS USED, SAY A-

$F_{SU} = .7\,(36.) = 25.0$ KSI

$q_{YIELD\ STEEL} = 25.0\,(.046) = 1160$ LB/IN (STEEL LOAD)

$q_{YIELD\ TOTAL} = \frac{1160}{.617} = 1880$ LB/IN (TOTAL SHEAR FLOW)

DEVELOPS $F_s = \frac{720}{.75} = 960$ PSI IN PLYWOOD

[illegible] CAN [illegible] 1800 PSI [illegible] $q' = 840\,([illegible]) = [illegible]$

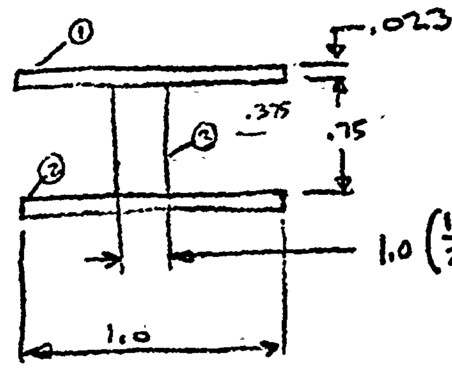
[illegible] $q_{TOTAL} = 1880 + 630 = 2510$ LB/IN

JOT 8-12-71

TRICON

W. DOOR PANEL

CHECK DOOR PANEL BY CONVERTING TO STEEL PANEL.



$1.0\left(\frac{1.1}{29}\right) = .038''$

ELEM	A	y	Ay	Ay^2	I_o	A_{ACTUAL}
1	.023	.386		.00343	.00000101	.023
2	.023	-.386		.00343	.00000101	.023
3	.0285	0		0	.00134	.750
	.0745			.00686	.00134	.796

$I = .00820$

$\rho_{EQUIV} = \left(\frac{.00820}{.796}\right)^{1/2} = (.0103)^{1/2} = .102$

FOR SOLID SECTION, $\rho = .289\ t$

$t_{EQUIVALENT} = \frac{.102}{.289} = .353''$

SIMPLE SUPPORTS

$F_{SCR} = 5.5(29)(10)^6\left(\frac{.353}{38.8}\right)^2 = 5.5(29)(82.8) = 13{,}200$ PSI

(.0091)

$q_{CRIT} = 13{,}200\,(.796) = 10{,}400.$ LB/IN

TRICON

PLYWOOD PANELS – SUMMARY

	$q_{CRITICAL}$ (LB/IN)			$F_{S_{CR}}$ (PSI)		
	SIMPLE SUPPORTS	FIXED SUPPORTS	50% FIXED	SIMPLE SUPPORTS	FIXED SUPPORTS	50% FIXED
SIDE PANEL						
1/2" PLYWOOD + FIBERGLASS	283	459	370	251 [1] 32	407 [1] 51	329 [1] 41
1/2 PLYWOOD	168	274	221	336	546	442
DOOR PANEL						
3/4" PLYWOOD + STEEL	10,350 [2]	16,800 [2]	13,500 [2]	13,000 [2]	21,000 [2]	17,000 [2]
3/4" PLYWOOD	1700 [3]	2740 [3]	2220 [3]	2260 [3]	3660 [3]	2960 [3]

[1] PLYWOOD STRESS

[2] LIMITED BY STEEL YIELDING AT $q = 1160$ LB/IN. ASSUME STEEL CARRIES THIS LOAD UNTIL THE PLYWOOD LOADS INCREASE TO ULTIMATE, $q_{TOTAL\ ULT} = 2510$ LB/IN
$F_{S_{STEEL}} = 25.0$ KSI, $F_{S_{PLYWOOD}} = 1800$ PSI

[3] LIMITED BY $F_{SU} = 1800$ PSI ; $q = 1350$ LB/IN

JOT 8-[illegible]

TRICON

PLYWOOD PANELS – SUMMARY CONT'D

LIFTING LOADS

ALL PANELS APPEAR TO BE CAPABLE OF DISTRIBUTING THE LIFTING LOADS ($q \approx 230$ LB/IN).

LATERAL RACKING LOADS

BLIND SIDE PANEL – THE BLIND SIDE PANEL IS NOT CAPABL[illegible] OF DISTRIBUTING THE LATERAL RACKING LOAD. ($q \approx 450$ LB/IN) BY ITSELF. HOWEVER, A RELATIVE STIFFNESS ANALYSIS WOULD PROBABLY SHOW THAT AT LEAST 25% OF THE LOAD COUL[illegible] BE DISTRIBUTED BY THE SECONDARY LOAD PATH THROUGH THE TOP, DOOR, AND SIDE PANELS. THIS WOULD REDUCE THE APPLIED LOAD TO ACCEPTABLE LEVELS ON ALL PANELS.

DOOR PANEL – THE DOOR PANEL IS CAPABLE OF DISTRIBUTING THE LATERAL RACKING LOAD. THE HINGES AND LATCHES MUST BE CAPABLE OF CARRYING THE LOADS, BUT NO ANALYSIS WAS PERFORMED ON THESE COMPONENTS.

SIDE PANEL – THE SIDE PANELS ARE NOT CAPABLE OF DISTRIBUTING THE ENTIRE RACKING LOAD THAT COULD OCCUR (IF THE DOOR WERE OPEN, FOR EXAM[illegible] THE SIDE PANELS APPEAR TO BE GOOD FOR THE LOADS BASED ON A RELATIVE STIFFNESS APPROAC[illegible]

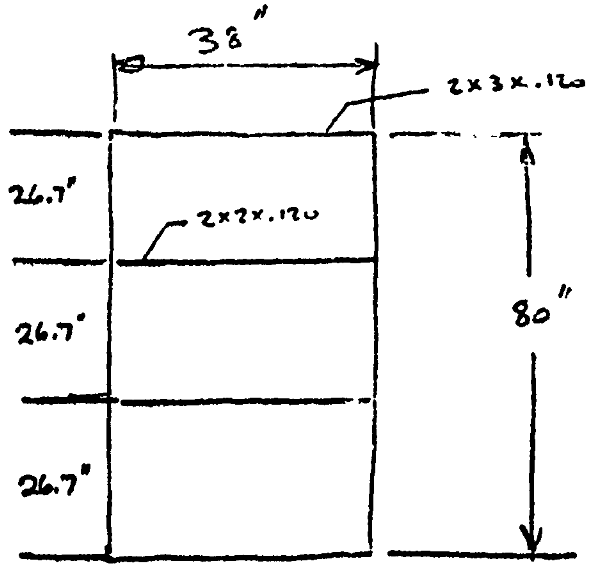
LONGITUDINAL RACKING LOADS

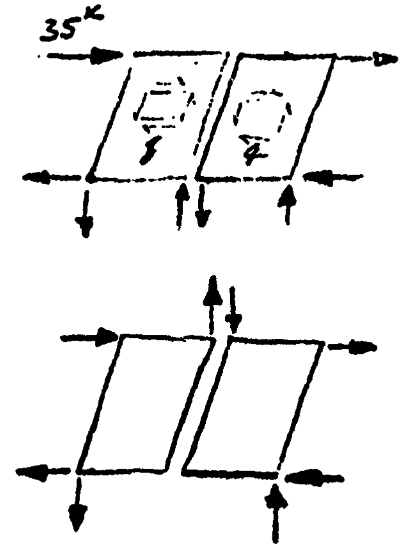
SIDE PANEL – THE SIDE PANELS ARE VERY CLOSE TO BEING CAPABLE OF DISTRIBUTING THE LOADS ([illegible] AN ANALYSIS BASED ON RELATIVE STIFFNESS WOUL[illegible] INCREASE THE MARGIN OF SAFETY.

CONCLUSION: THE PLYWOOD PANELS APPEAR TO BE ADEQUATE [illegible] [illegible] LOADS APPLIED, AND THE [illegible] [illegible] [illegible] THAN A [illegible] ATTACHED STA[illegible]

IKIKON

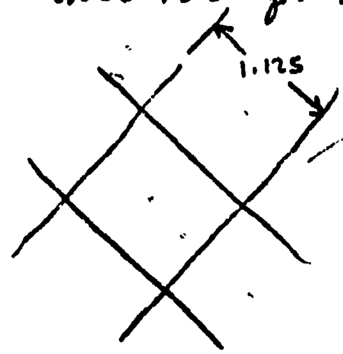
DOOR





ASSUME $q = \frac{35{,}000}{2(38)} = 460$ LB/IN → USE 450 LB/IN

FOR STABILITY, THIS WILL REQUIRE THE PREVIOUSLY CALCULATED PUNCHED PANEL GAGES. FIND $\bar{t}$ OF 1.0" SQUARE PUNCH W=.125 t=.1046 (A=.0131 IN²) THAT WAS GOOD FOR q = 450 LB/IN.



AREA $= (1.125)^2 = 1.265$ IN²

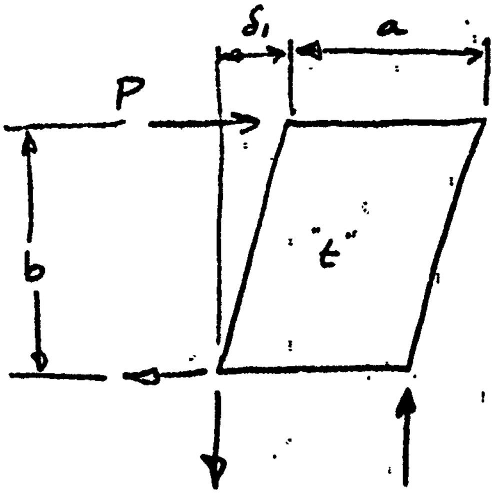
VOLUME $= (.0131)(1.125)(2) = .0295$ IN³

$\bar{t} = \frac{.0295}{1.265} = .0233$ (NOT GOOD FOR WEIGHT CALC'S)

TRICON

DOOR

FIND DOOR STIFFNESS — SHEAR DEFLECTION + BENDING DEFLECTION.



SHEAR DEFLECTION

$$\delta_1 = \frac{Pb}{atG}$$

STABLE IN SHEAR — FIND SHEAR DEFLECTION:

$$\delta_1 = \frac{Vb}{A_w G}$$

ASSUME $G = 11.0(10)^6$

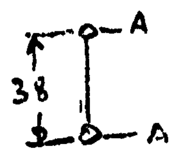
$P = \frac{35.0^K}{2} = 17.5^K \equiv 460 \frac{LB}{IN}(38") = 17.5^K$

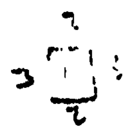
$a = 38.0 \qquad b = 80.0$

$$\delta_1 = \frac{17{,}500(80)}{38(.0233)(11)(10)^6} = \frac{1400}{9750} = .143" \text{ (SHEAR DEFLECTION)}$$

BENDING DEFLECTION

$$\delta_2 = \frac{Pb^3}{3EI}$$





FIND I; ASSUME $A = 10(.12) = 1.20 \text{ IN}^2$

$$I \approx \frac{Ad^2}{2} = \frac{1.20(38)^2}{2} = .6(1440) = 866 \text{ IN}^4$$

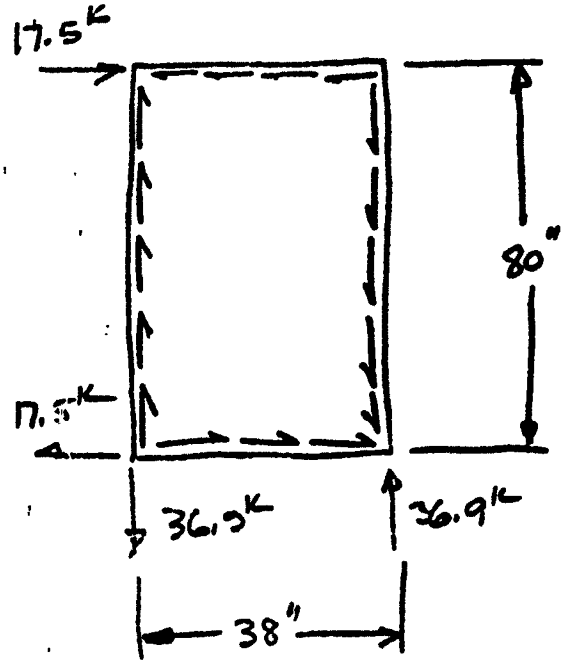
$$\delta_2 = \frac{17{,}500(80)^3}{[illegible]} = \frac{8.950}{[illegible]} = .0895$$

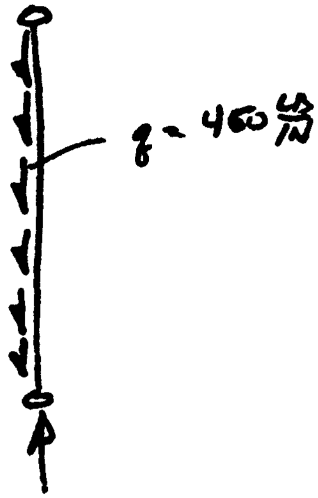
[illegible]

Door

$\delta_{TOTAL} = \delta_1 + \delta_2 = .143 + .090 = .233$ IN

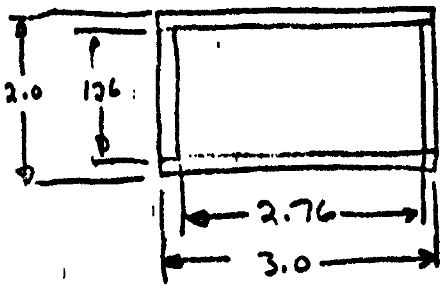
CHECK DOOR FRAME COLUMN.





$C = 1.87 \quad \frac{1}{\sqrt{C}} = .732$

$\ell' = .732(80) = 58.6$



$I_1 = \frac{3.0(2.0)^3}{12} = 2.0 \text{ IN}^4$

$I_2 = \frac{2.76(1.76)^3}{12} = 1.25$

$\therefore I_{MIN} = .75 \text{ IN}^4 \quad A = 1.20 \text{ IN}^2$

$$\rho = \left(\frac{.75}{1.2}\right)^{1/2} = (.625)^{1/2} = .791$$

$$\frac{\ell}{\rho} = \frac{80.}{.791} = 101 \quad \frac{\ell'}{\rho} = \frac{\ell}{\rho\sqrt{C}} = 101(.732) = 74.0$$

TRICON
DOOR

$$P_{CR} = \frac{\pi^2 EI}{(\ell')^2} = \frac{9.86(29)(10)^6(.75)}{(58.6)^2} = \frac{214\ (10)^3}{3.440}$$

$P_{CR} = 62{,}400$ LBS

$$F_{CR} = \frac{\pi^2 E}{\left(\frac{\ell'}{\rho}\right)^2} = \frac{9.86(29)(10)^6}{(74.)^2} = \frac{286\ (10)^3}{5.470}$$

$F_{CR} = 52{,}300$ PSI (REQUIRES A STEEL WITH ABOUT 60.0 KSI F_{cy} FOR TANGENT MODULUS)

$$f = \frac{36.9^k}{1.2\ \text{IN}^2} = 30.7\ \text{KSI}$$

CALCULATE CRIPPLING STRESS

$$\frac{b}{t}\ (\text{MAX}) = \frac{3.0}{.12} = 25.0$$

ASSUME $\frac{F_{cc}}{\sqrt{F_{cy}E}} = .06$ USE $F_{cy} = 60.0$ $E = 29(10)^3$

$$F_{cc} = .06\left[\overset{1740}{60(29)(10)^3}\right]^{1/2} = .06\left[174\right]^{1/2}(10)^2 = 6(13.2) = 79.0$$

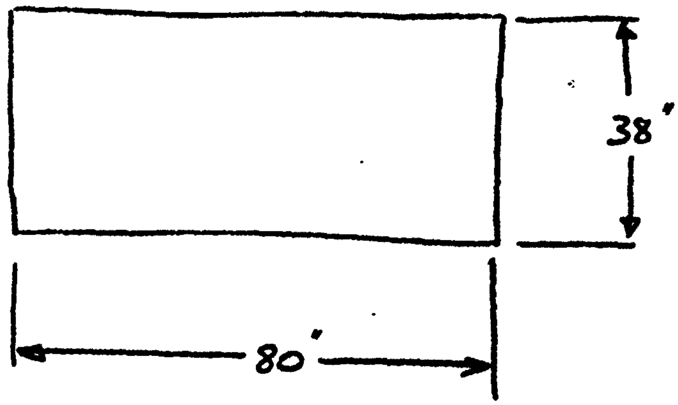
USE $F_{cc} = F_{cy} = 60.0$ KSI

$$M.S. \approx \frac{52.3}{30.7} - 1 = \underline{+.70}$$

[illegible]

Door

CHECK OUT-OF-PLANE LOADS



$$\frac{a}{b} = \frac{80}{38} = 2.1$$

ASSUME $\eta_1 = .16 - \frac{.1}{.5}(.035) = .153$ (.147)

$\eta_2 = .336 - \frac{.1}{.5}(.032) = .330$

$$w_{MAX} = \eta_1 a \left(\frac{qa}{Et}\right)^{1/3} \qquad q = p = 1.27 \text{ psi}$$

$$= .153(80)\left[\frac{\overset{101.5}{1.27(80)}}{\underset{.676}{29(10)^6(.0233)}}\right]^{1/3} = 12.25\left[150(10)^{-6}\right]^{1/3}$$

$$= 12.25(5.32)(10)^{-2} = .065''$$

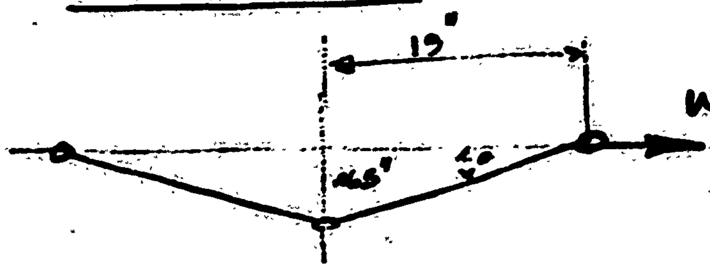
$$S_{MAX} = \eta_2\left[E\left(\frac{qa}{t}\right)^2\right]^{1/3} = .330\left[29(10)^6\left(\frac{\overset{.15}{1.27(80)}}{\underset{4.35}{.0233}}\right)^2\right]^{1/3}$$

$$= .33\left[29\underset{549}{(19.0)}(10)^{12}\right]^{1/3} = .33(8.2)(10)^3 = 2700 \text{ psi}$$

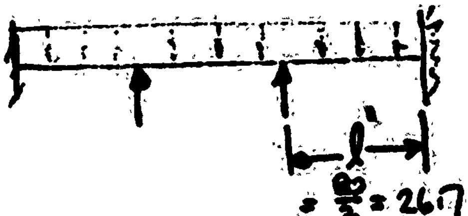
TRICON

DOOR

O-O-P LOADS

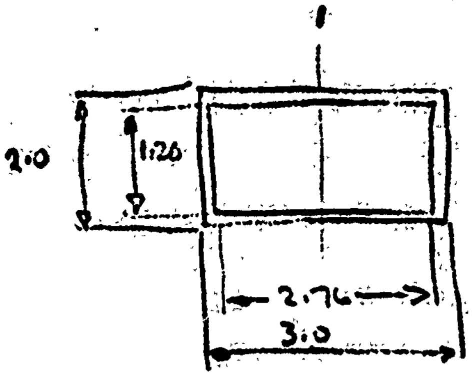


ASSUME $w = ft = S_{MAX} t = 2700(.0233) = 63$ LB/IN



ASSUME $M_{MAX} = \frac{w(l')^2}{12}$

$$M_{MAX} = \frac{63(26.7)^2}{12} = 3740 \text{ IN·LB}$$

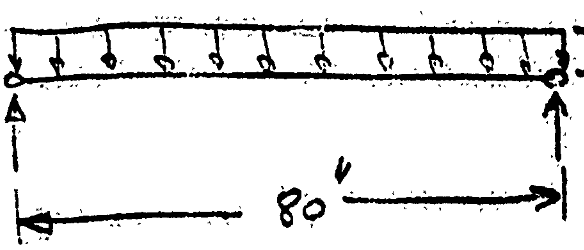


$$I_1' = \frac{2.0(3.0)^3}{12} = 4.50 \text{ IN}^4$$

$$I_2' = \frac{1.76(2.76)^3}{12} = 3.08 \text{ IN}^4$$

$$I_{MAX} = 1.42 \text{ IN}^4$$

$$f_b = \frac{3740(1.5)}{1.42} = 3950 \text{ PSI}$$



$w = 1.27(19) = 24.2$ LB/IN

$$R = \frac{wl}{2} = \frac{24.2(80)}{2} = 956 \text{ LB}$$

$$M_{MAX} = \frac{wl^2}{8} = \frac{24.2(80)^2}{8} = 19,400$$

$I_{MIN} = .75$ $c = 1.0$ $f_b = \frac{19,400(1.0)}{.75} = 25,9$[illegible]

$MS = \frac{[illegible]}{[illegible]} - 1 = \underline{+.93}$

TRICON

DOOR

O-O-P LOADS

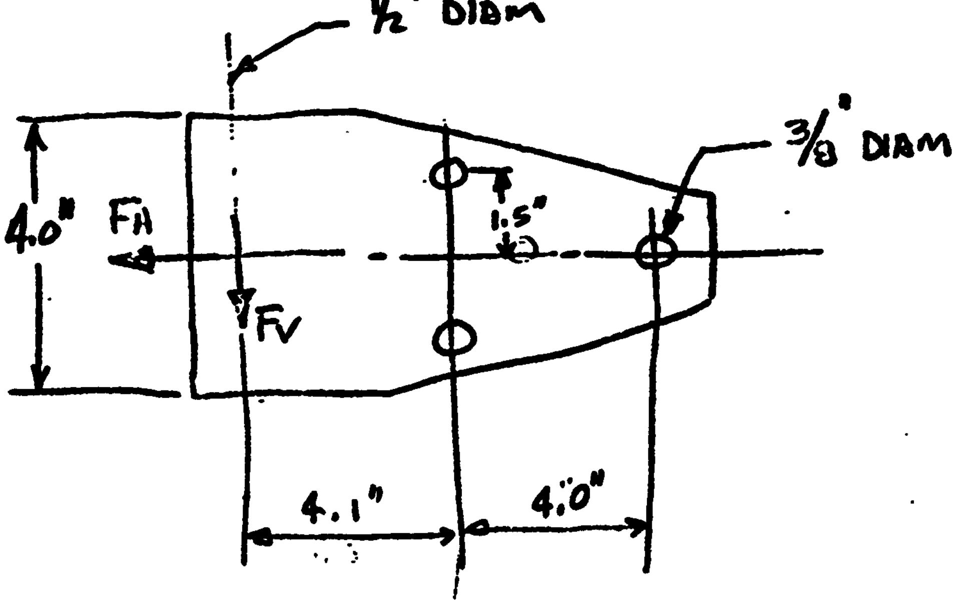
$$\delta_{DF} = \frac{wl^4}{24EI} = \frac{24.2\overset{41.0(10)^6}{(30)^4}}{24(29)(10)^6(.75)} = \frac{991}{521} = 1.90''$$

MAXIMUM DEFLECTION FOR DOOR OUT-OF-PLANE LOAD

$$\delta_T = \delta_{DF} + \delta_P = \delta_{DF} + w_{MAX} = 1.97'' \approx 2.00''$$

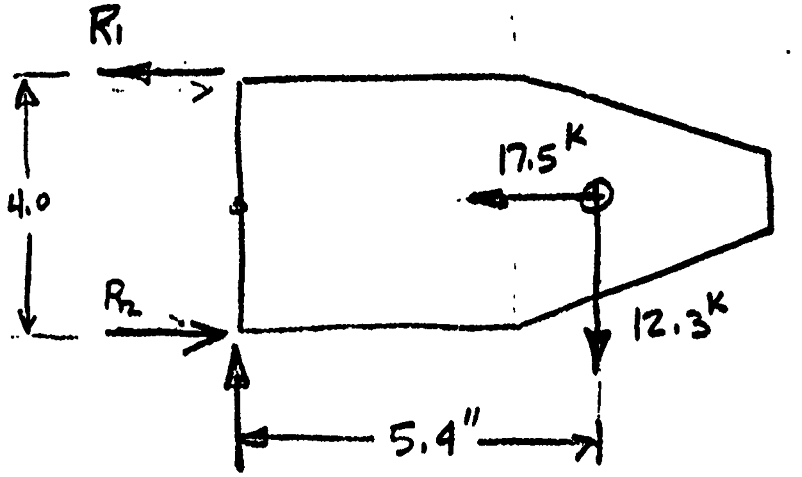
TRIKON

HINGE LOADS



HINGE REACTIONS – ASSUME THREE HINGES SHARE VERTICAL LOAD

$$F_H = 17.5^K$$
$$F_V = 36.9^K/3 = 12.3^K$$



$$R_1 = 12.3\left(\frac{5.4}{4.0}\right) - 17.5\left(\frac{1}{2}\right)$$
$$= 16.6 - 8.75 = 7.85^K$$

$$R_2 = 16.6 + 8.75 = 25.35^K$$

THE $\frac{1}{2}$" DIAMETER HINGE BOLT SHOULD BE MINIMUM OF 156 KSI SHEAR. $P_{ALLOW} = 30.6\ K$

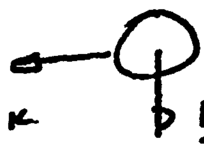
$$M.S. = \frac{30.6}{25.4} - 1 = \boxed{+.20}$$

TRICON

HINGE LOADS

ASSUME 3/8" BOLTS LOADED AS SHOWN

$\frac{17.5}{3} = 5.84^K$



$\frac{12.3}{2} = 6.2^K$

$$R = \left[(5.84)^2 + (6.2)^2\right]^{1/2} = \left[\overset{72.5}{34.0 + 38.5}\right]^{1/2} = 8.5^K$$

$P_{ALLOW} = 10.5 \quad (95 \text{ ksi } F_{SU})$

$$MS = \frac{10.5}{8.5} - 1 = \underline{\underline{+.24}}$$

TRICON

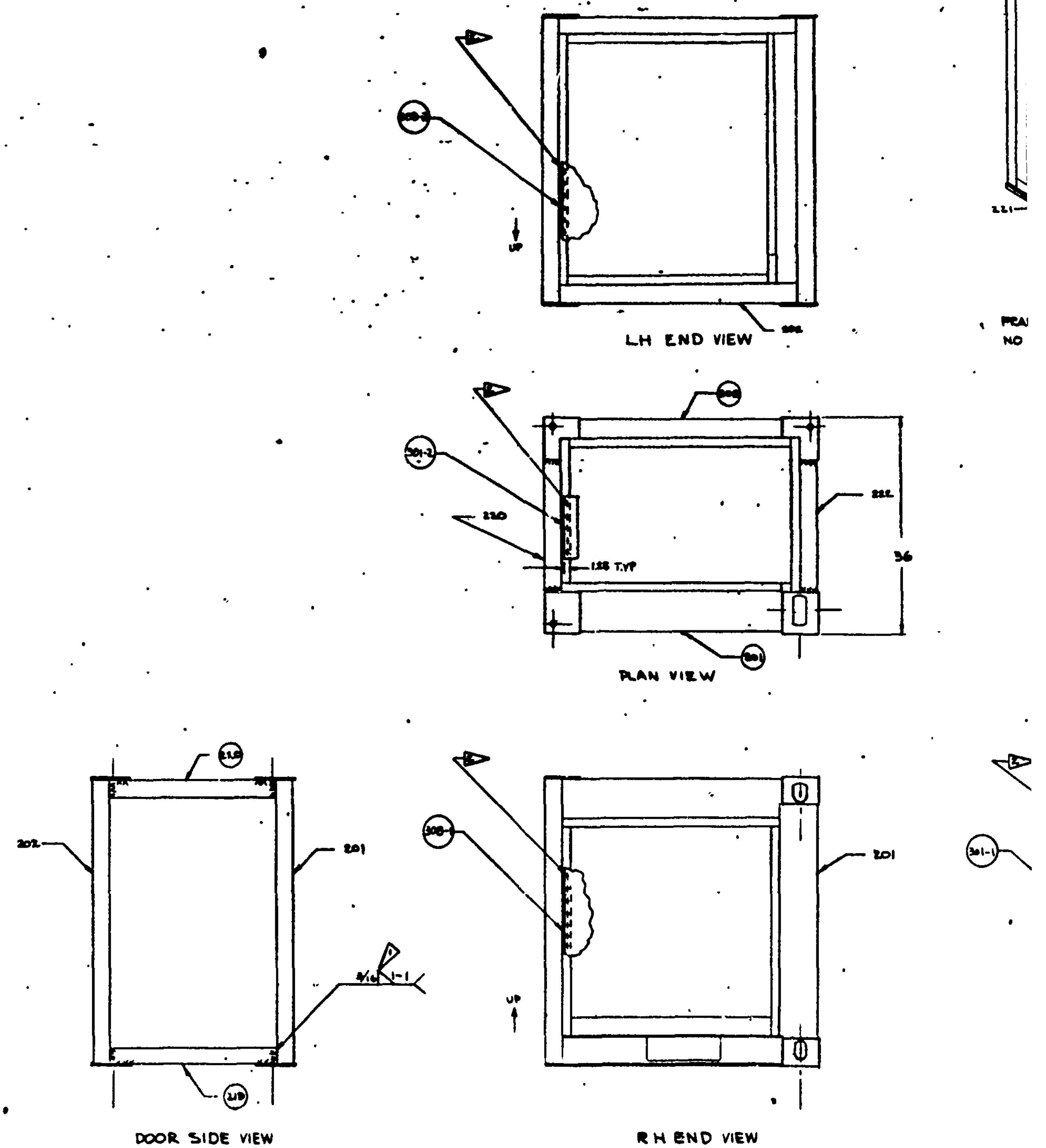
DOOR

CONCLUSION: THE MOLDED DOOR CONCEPT IS STRUCTURALLY FEASIBLE. THE DISTRIBUTION OF THE LATERAL RACKING LOAD CAN BE ACCOMPLISHED IF THE HINGES AND LATCH MECHANISMS ARE ADEQUATE. IN ADDITION, THE SIDE OF THE DOOR FRAME ADJACENT TO THE DOOR POST CAN BE MADE PARTIALLY EFFECTIVE IN DISTRIBUTING THE STACKING LOAD ON THE DOOR POST.

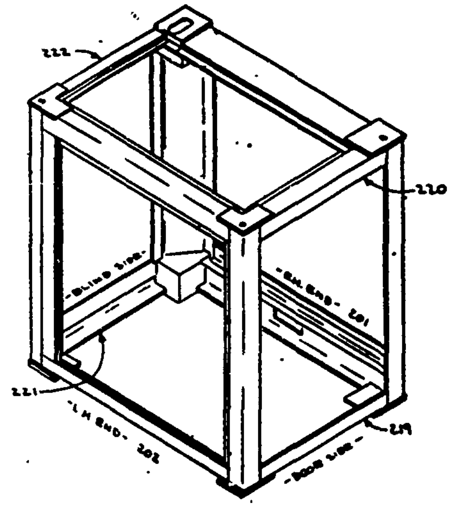
THE PROPOSED HINGE AND LATCH MECHANISMS APPEAR TO BE ADEQUATE ON A PRELIMINARY ANALYSIS BASIS.

APPENDIX C

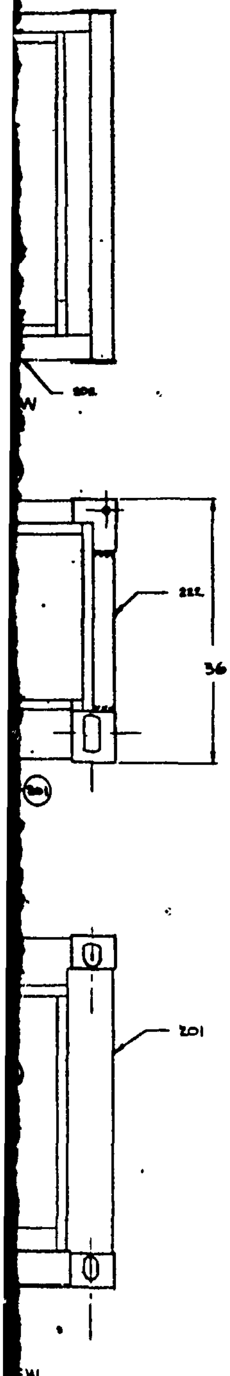
ENGINEERING DRAWINGS OF STEEL SUBSCALE TRICON CONTAINER



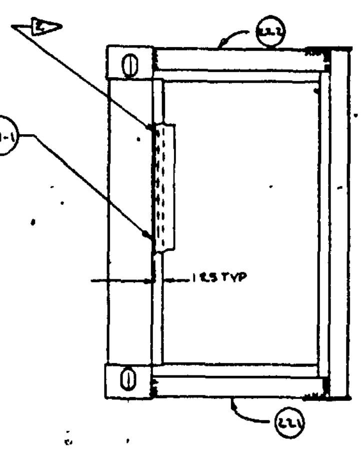
IOI SUBSCALE CONTAINER ASSY



FRAME GENERAL ARRANGEMENT
NO SCALE



ER ASSY



BLIND SIDE VIEW

1. REMOVE BURRS AND BREAK SHARP EDGES.
2. REMOVE ALL LOOSE HRS MILL SCALE.
3. REMOVE ALL OIL, PAINT AND OTHER FOREIGN MATERIAL FROM STOCK PRIOR TO ASSEMBLY. RECOMMENDED METHOD: SCRUB WITH M.E.K. OR OTHER APPROVED SOLVENT. WIPE OFF RESIDUE.
4. REMOVE RUST IN AREA OF WELDS PRIOR TO WELDING.

RIVET WITH DRIVEN HEAD INSIDE.

ALL WELDS USED TO JOIN CONTAINER TO BE INSIDE SKIP WELDED AS INDICATED

RIVET — 3/16 DIA × 5/8 FH 30FT ITEM

21 — 1 — CONTAINER-SUB SCALE

1/16 & NOTED

R677059 P02

TOOL DRAWING
THE BOEING COMPANY

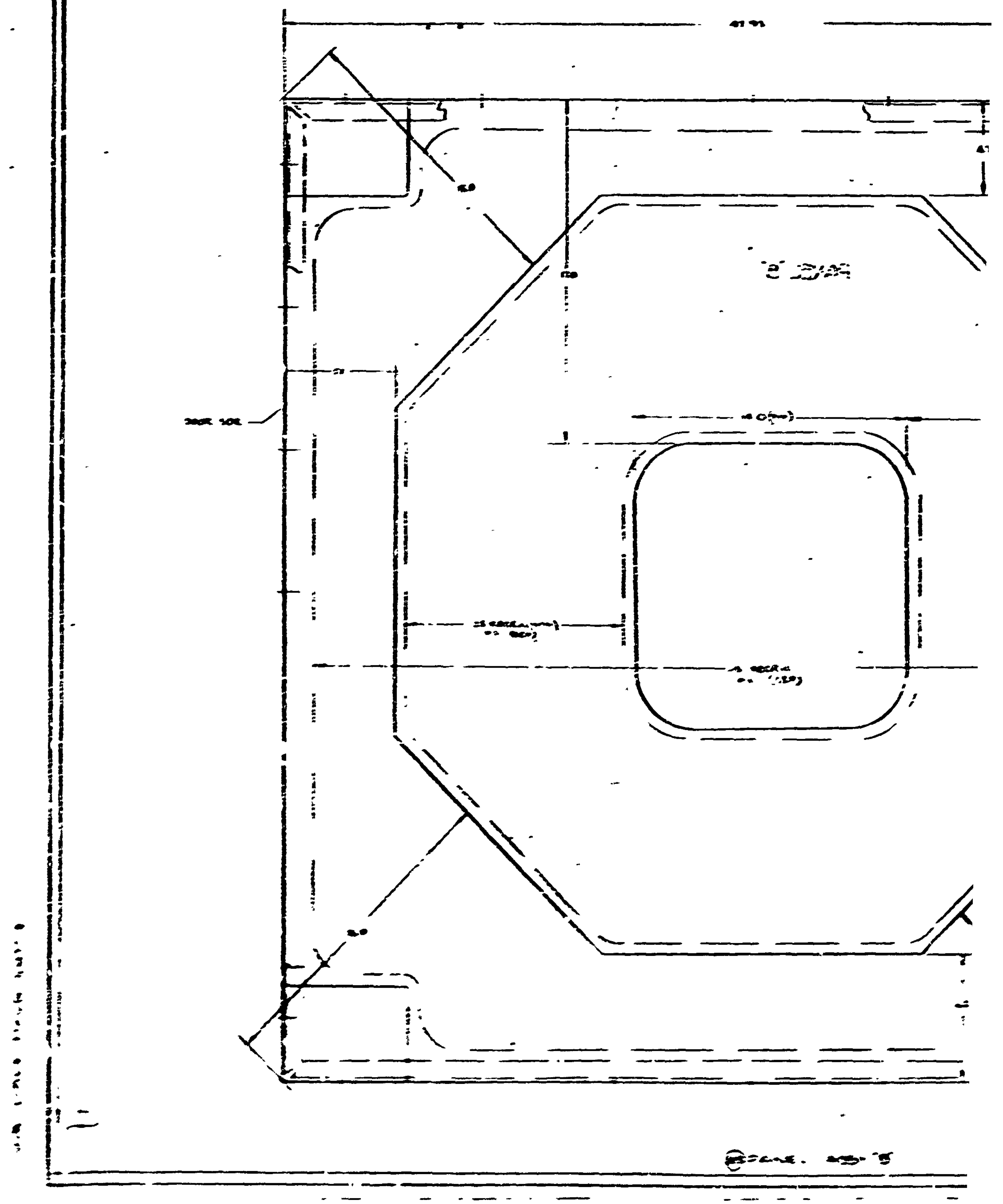
CONTAINER - SUB-SCALE

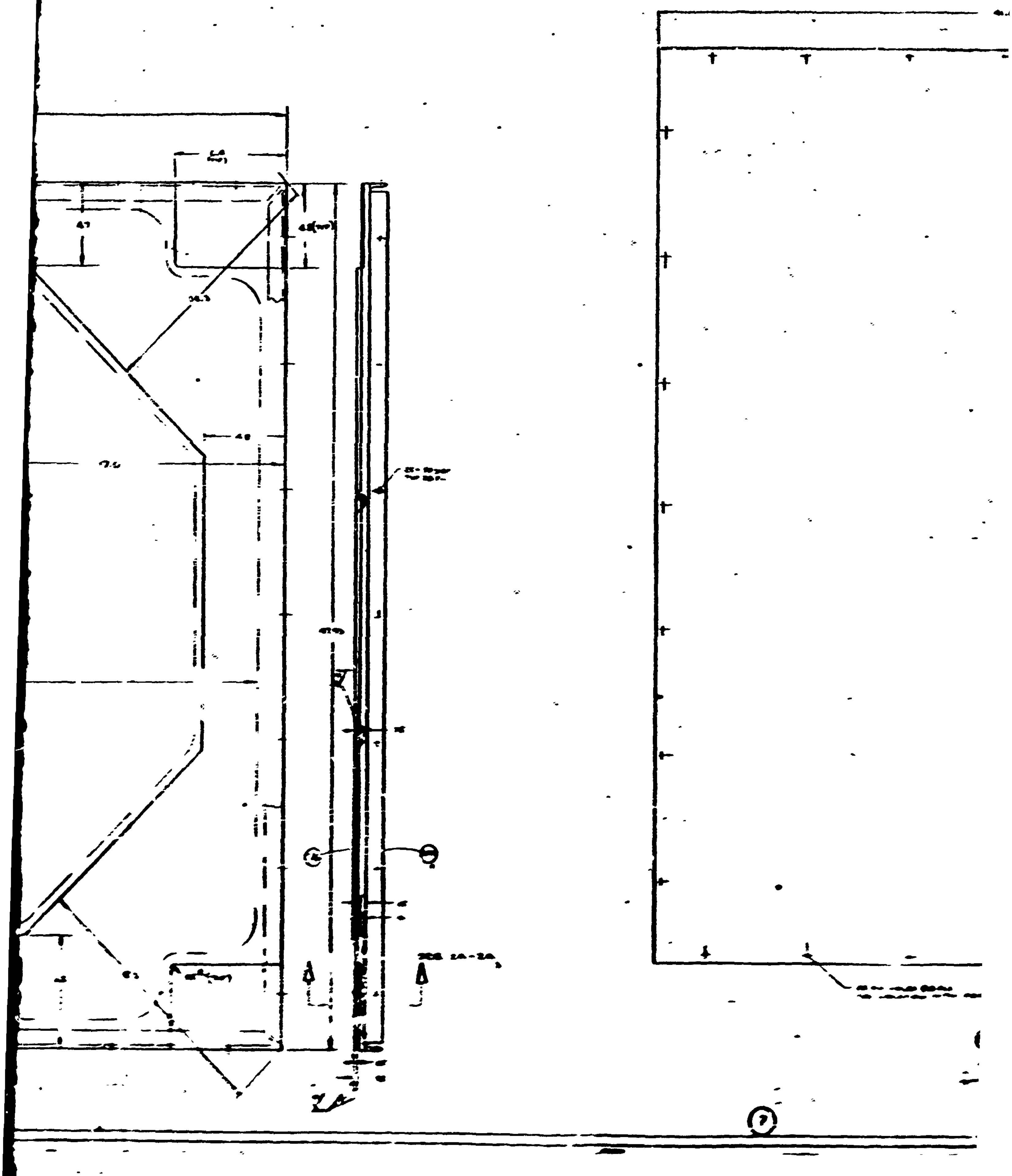
R677059 P02 — 1 of 3

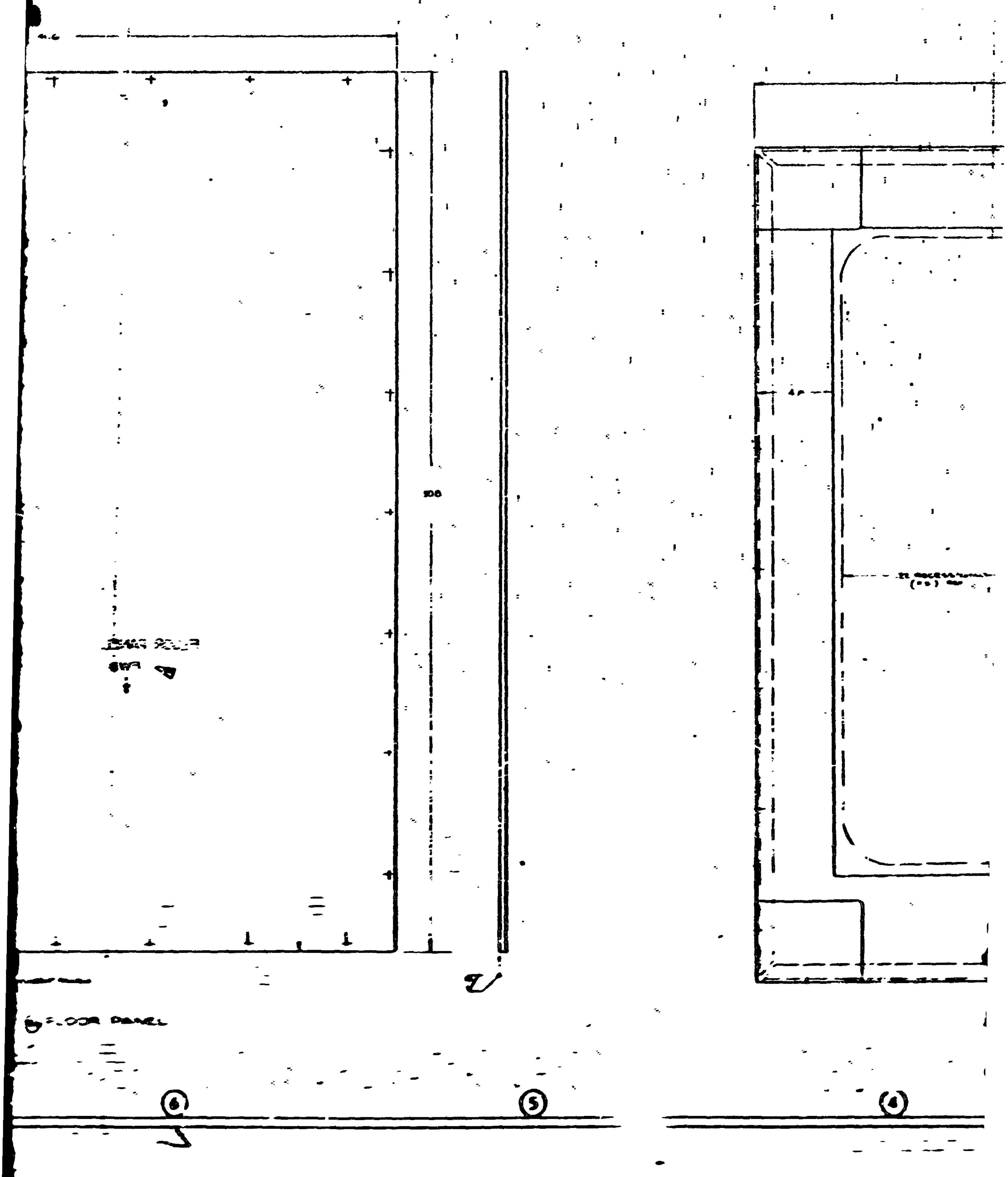
267

3

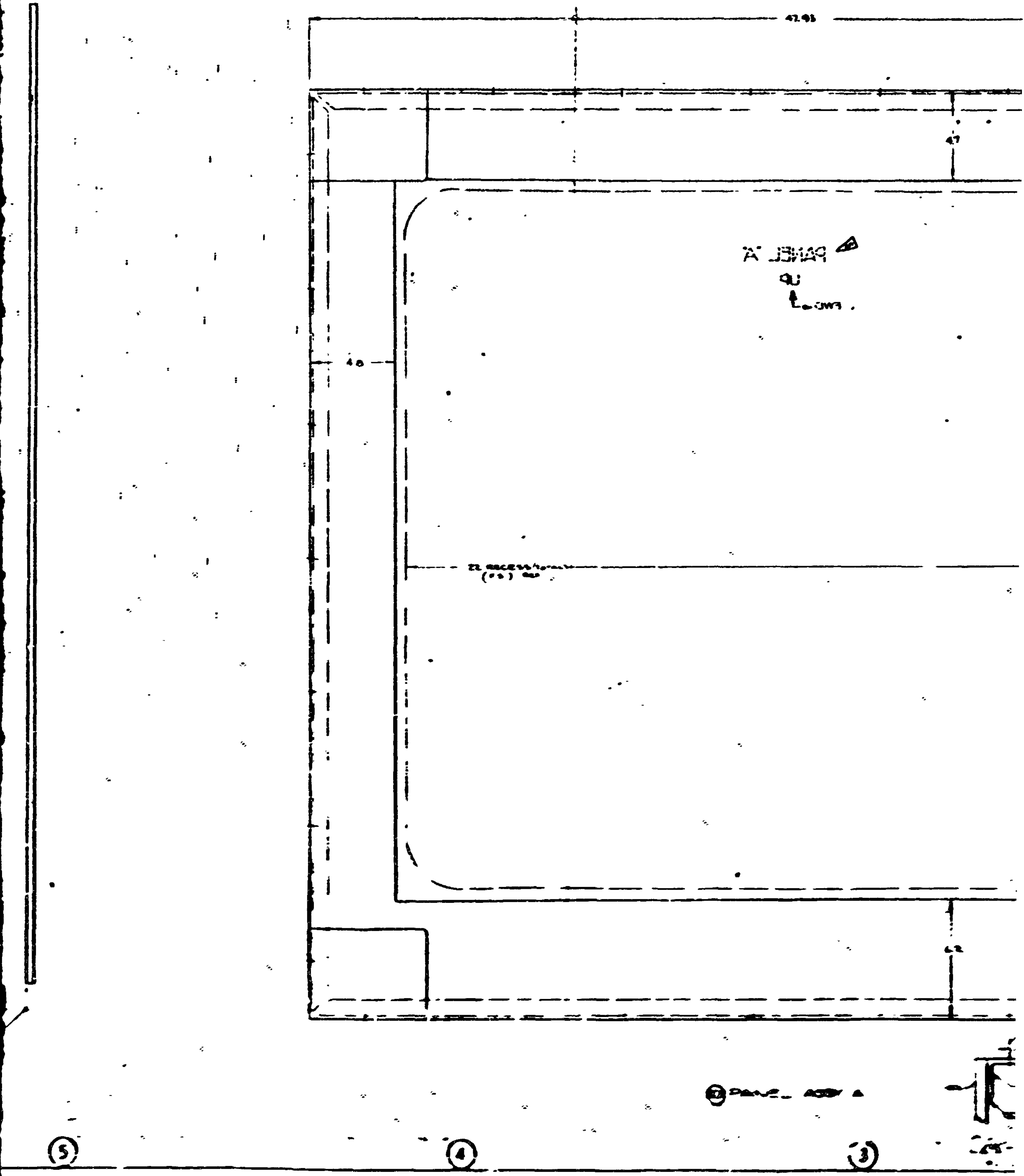
2



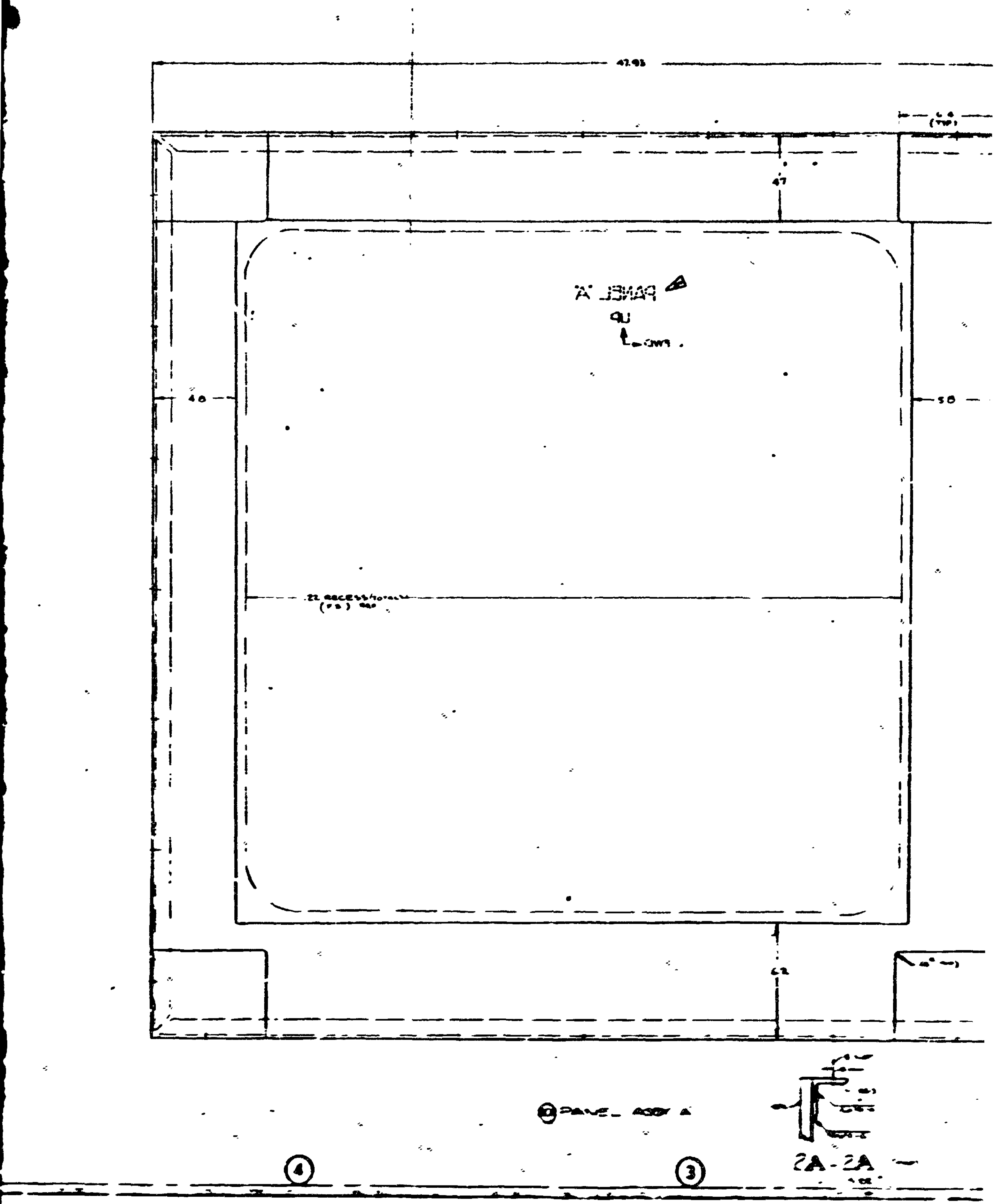




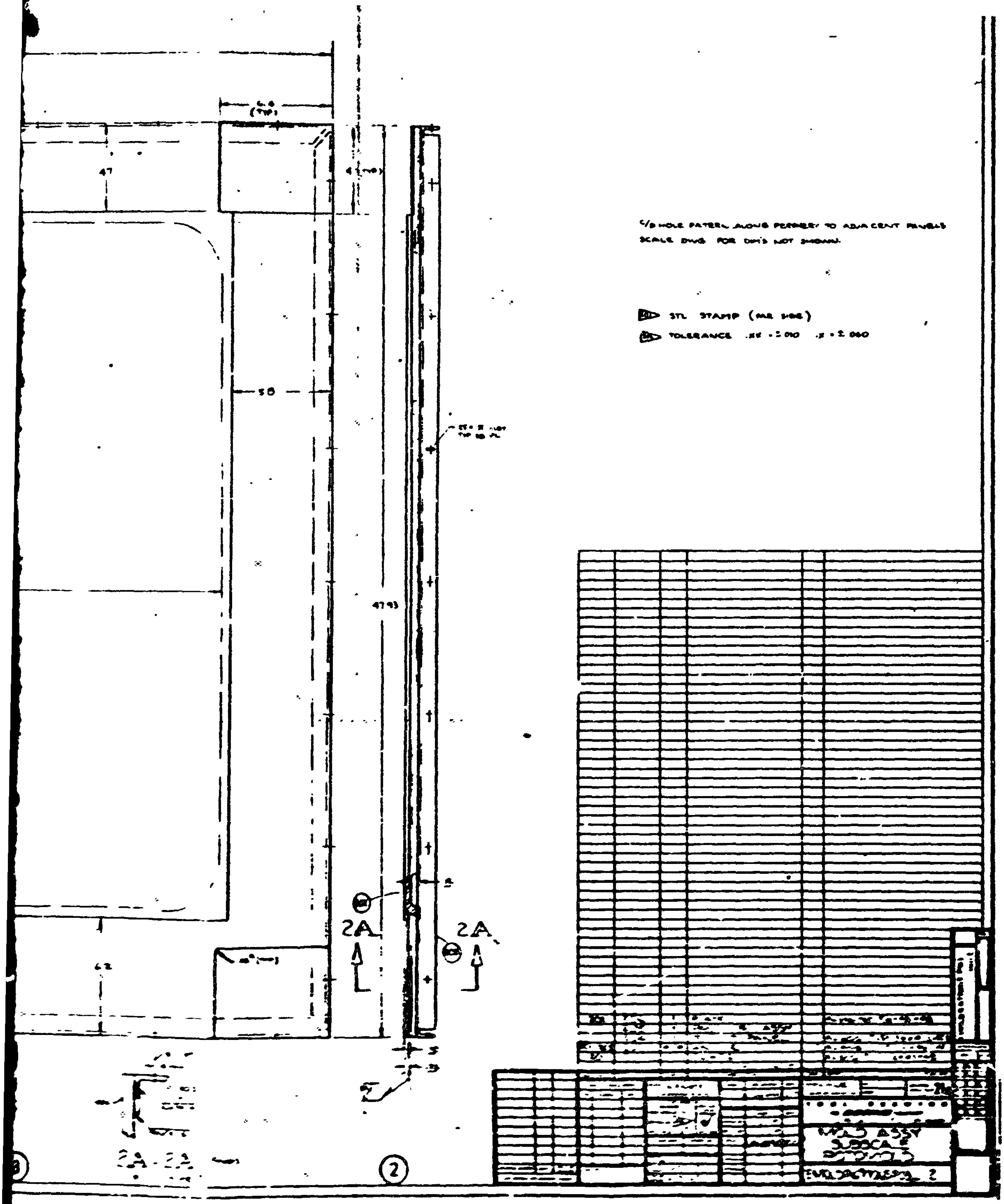
108
6
5
4

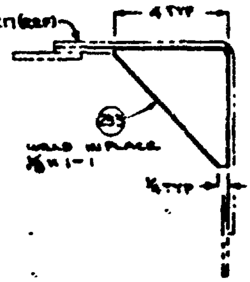


UP
5
4
3

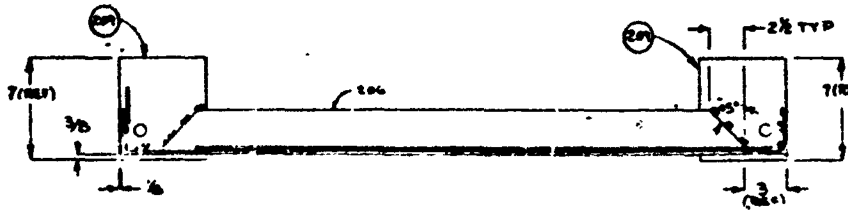


PANEL 'A'
UP
2A-2A
4
3

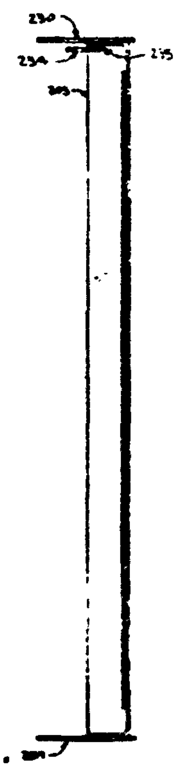

47
50
47.93
2A
2A
2A-2A
2
C/S HOLE PATTERN ALONG PERIPHERY TO ADJACENT PANELS
SCALE DWG FOR DIM'S NOT SHOWN
STL STAMP
TOLERANCE .XX ±.010 .X ±.060
MAS ASSY



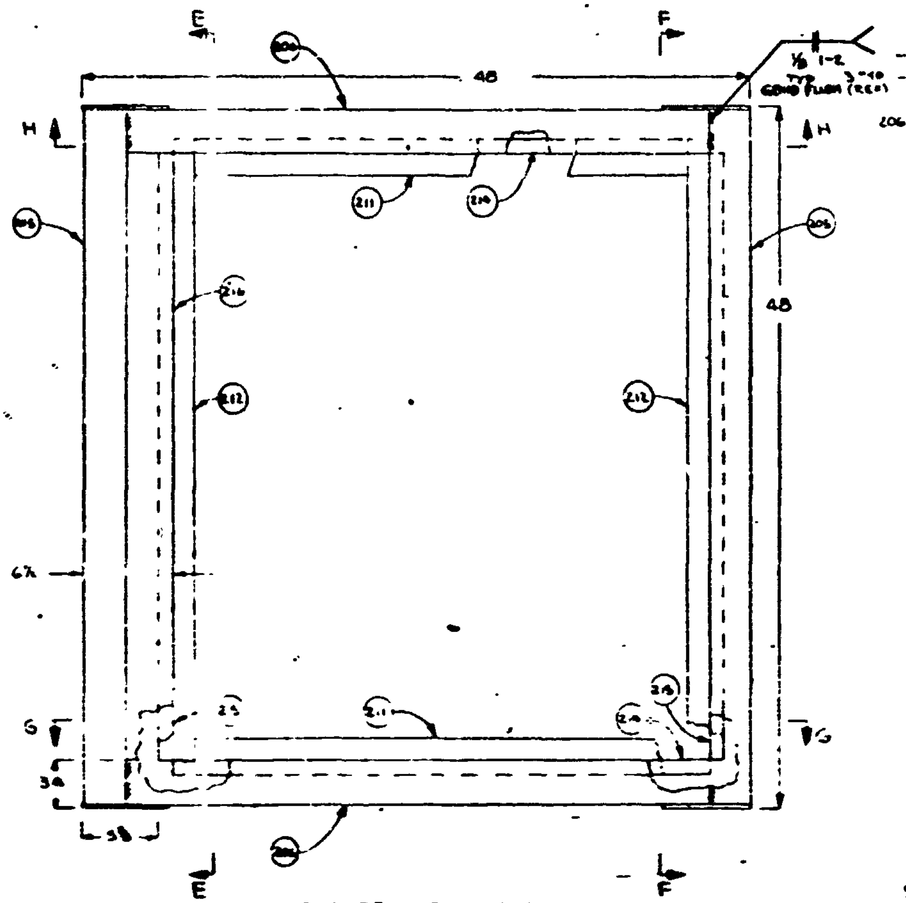
233 PLUG-UPPER RH RAIL
SCALE ½



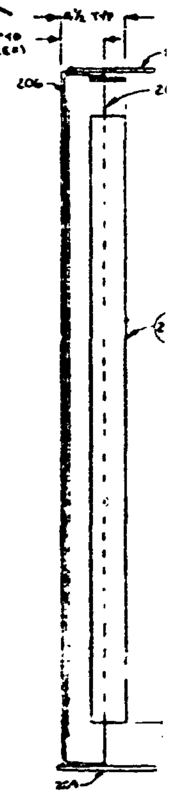
SEC. G-G
LOWER RAIL - L.H.



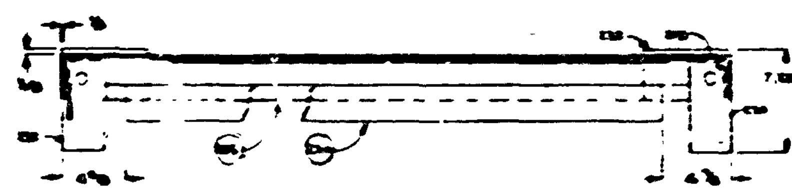
SEC. F-F
DOOR POST - LH

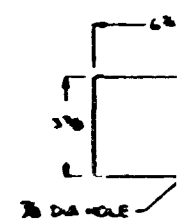


202 FRAME ASSY - LH



SEC E-E
BLIND POS

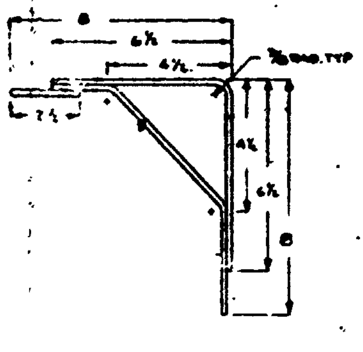




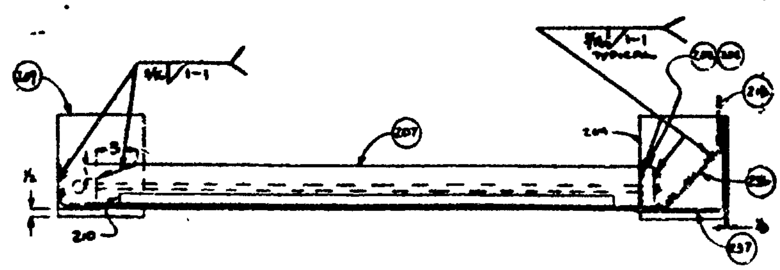
SEC H-H
UPPER RAIL - LH

7

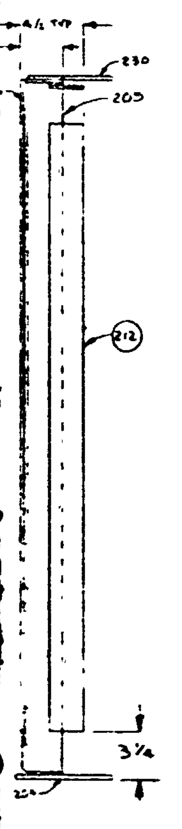
6



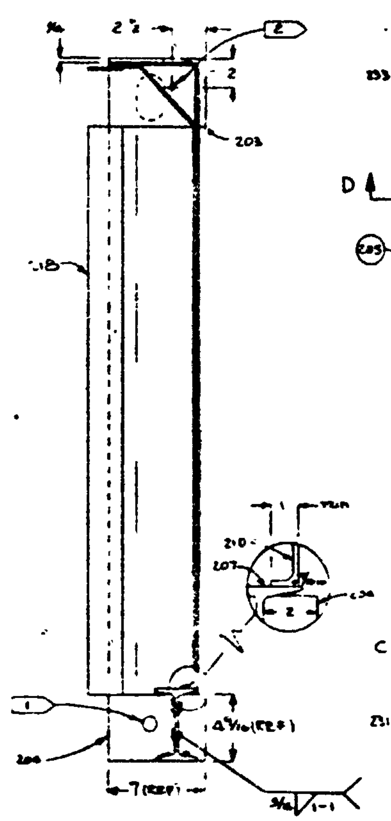
SEC I-I POST/RAIL 3
SCALE ½



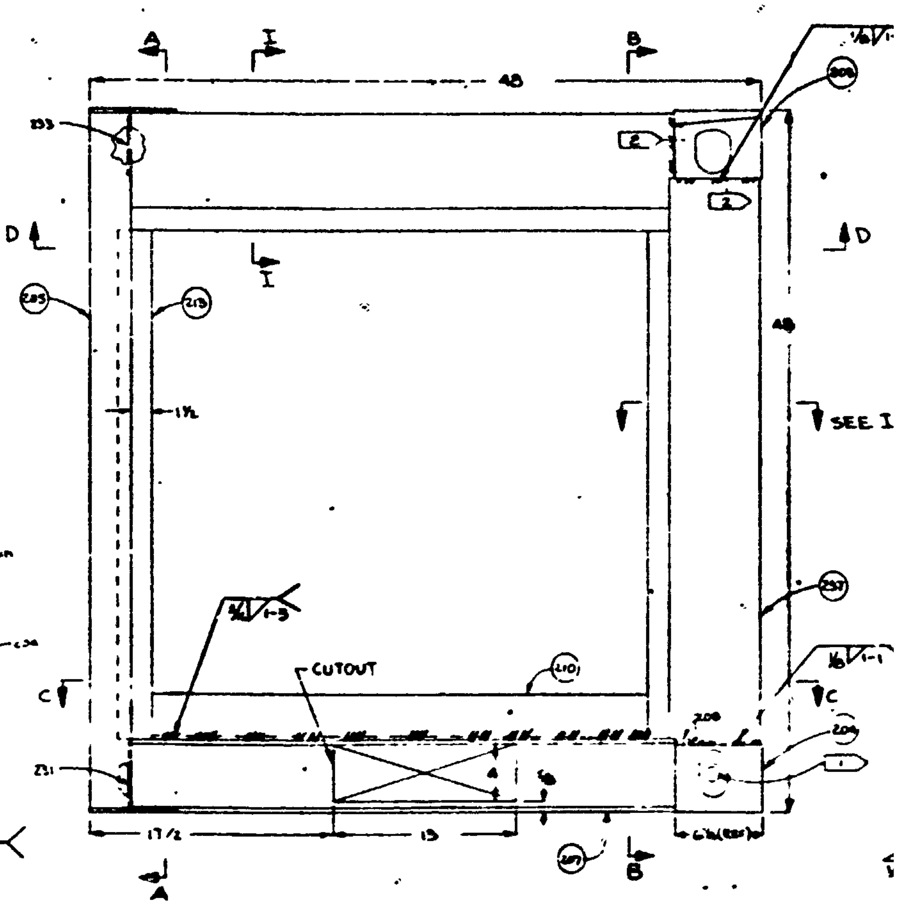
SEC. C-C
LOWER RAIL - R.H.



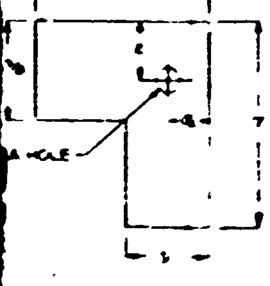
SEC E-E
BLIND POST - LH



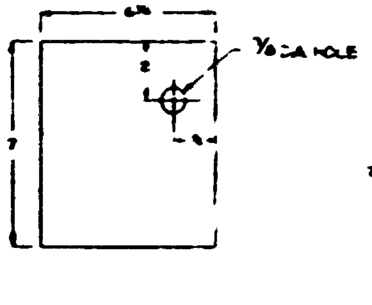
SEC B-B
BLIND POST - RH



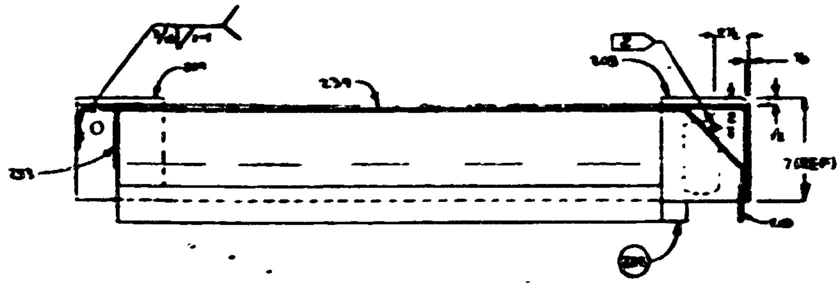
201 FRAME ASSY - R.H



230 CORNER PLATE
SCALE ½



209 CORNER PLATE
SCALE ½

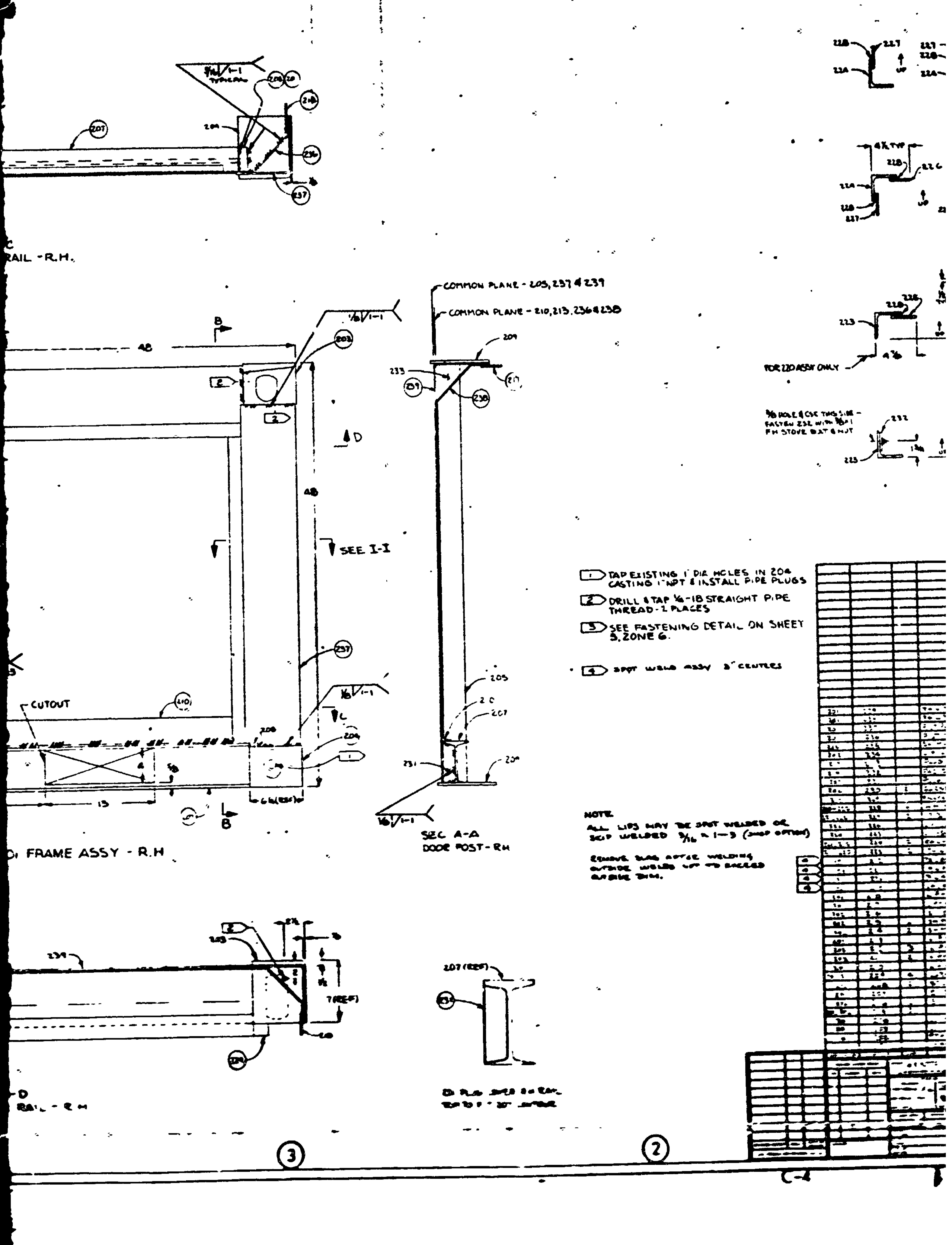


SEC D-D
UPPER RAIL - R.H

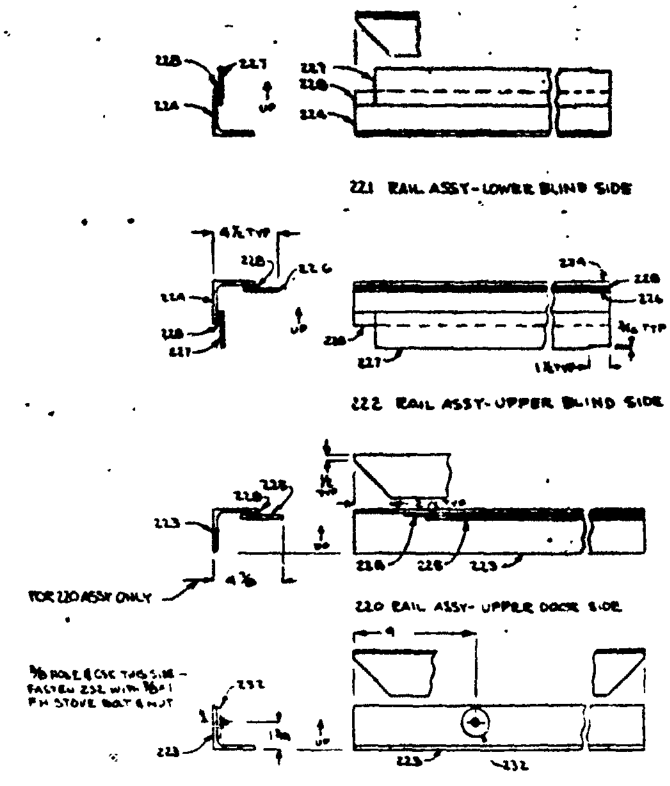
5

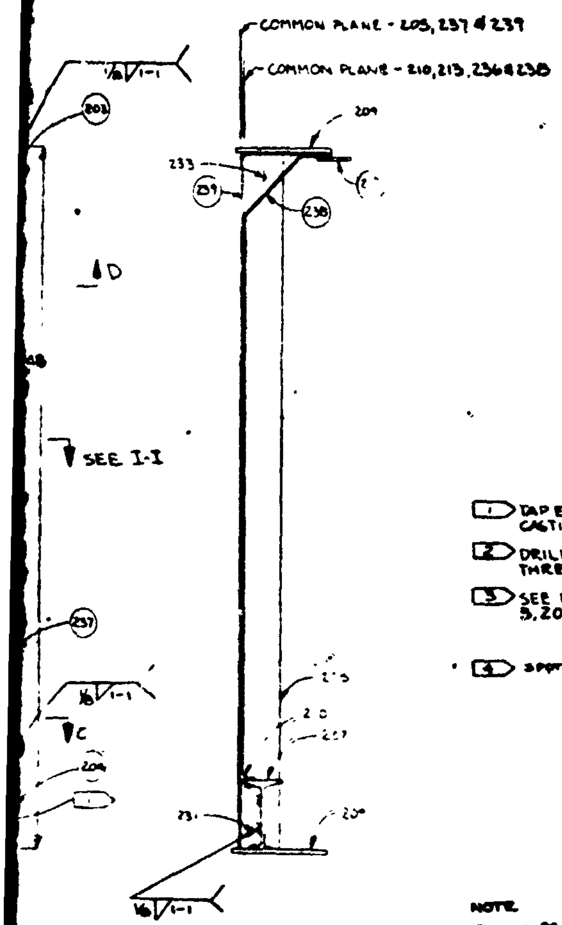
4

3



RAIL - R.H.
COMMON PLANE - 205, 237 & 239
COMMON PLANE - 210, 213, 236 & 238
SEE I-I
CUTOUT
FRAME ASSY - R.H
SEC A-A
DOOR POST - RH
FOR 220 ASSY ONLY
1 TAP EXISTING 1" DIA HOLES IN 204 CASTING 1" NPT & INSTALL PIPE PLUGS
2 DRILL & TAP ¼-18 STRAIGHT PIPE THREAD - 2 PLACES
3 SEE FASTENING DETAIL ON SHEET 5, ZONE 6.
4 SPOT WELD ASSY 3" CENTERS
NOTE
ALL LIPS MAY BE SPOT WELDED OR SKIP WELDED 3/16 x 1-3 (SHOP OPTION)
REMOVE SLAG AFTER WELDING OUTSIDE WELDS NOT TO EXCEED OUTSIDE DIM.
RAIL - R H
7 (REF)
207 (REF)
3
2
C-4

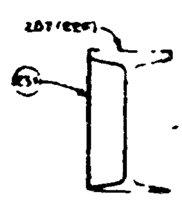


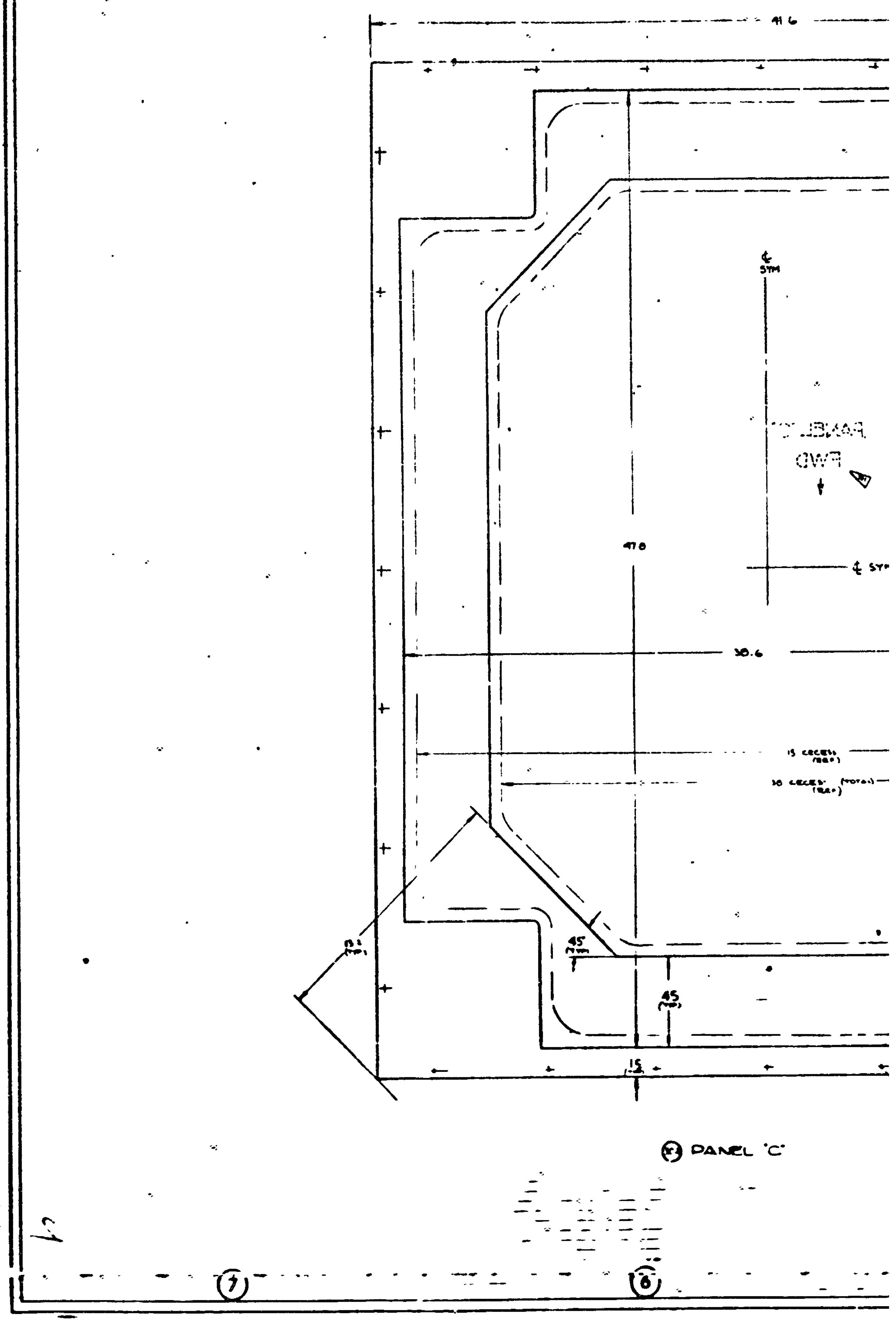


1. TAP EXISTING 1" DIA HOLES IN 204 CASTING 1" NPT & INSTALL PIPE PLUGS
2. DRILL & TAP ¼-18 STRAIGHT PIPE THREAD-2 PLACES
3. SEE FASTENING DETAIL ON SHEET 3, ZONE 6
4. SPOT WELD ASSY 3" CENTERS

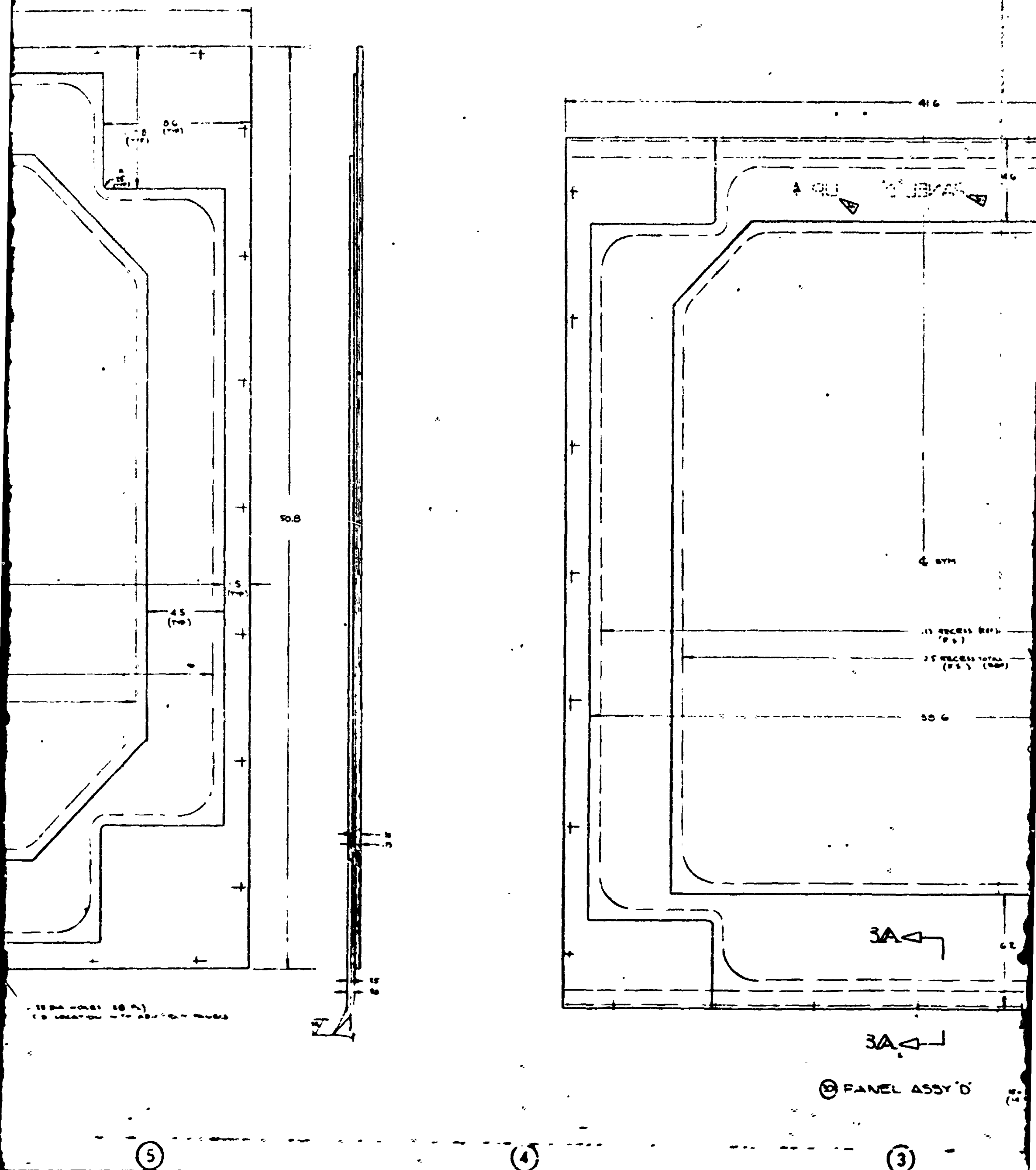
NOTE
ALL LIPS MAY BE SPOT WELDED OR SKIP WELDED 3/16 x 1-3 (SHOP OPTION)

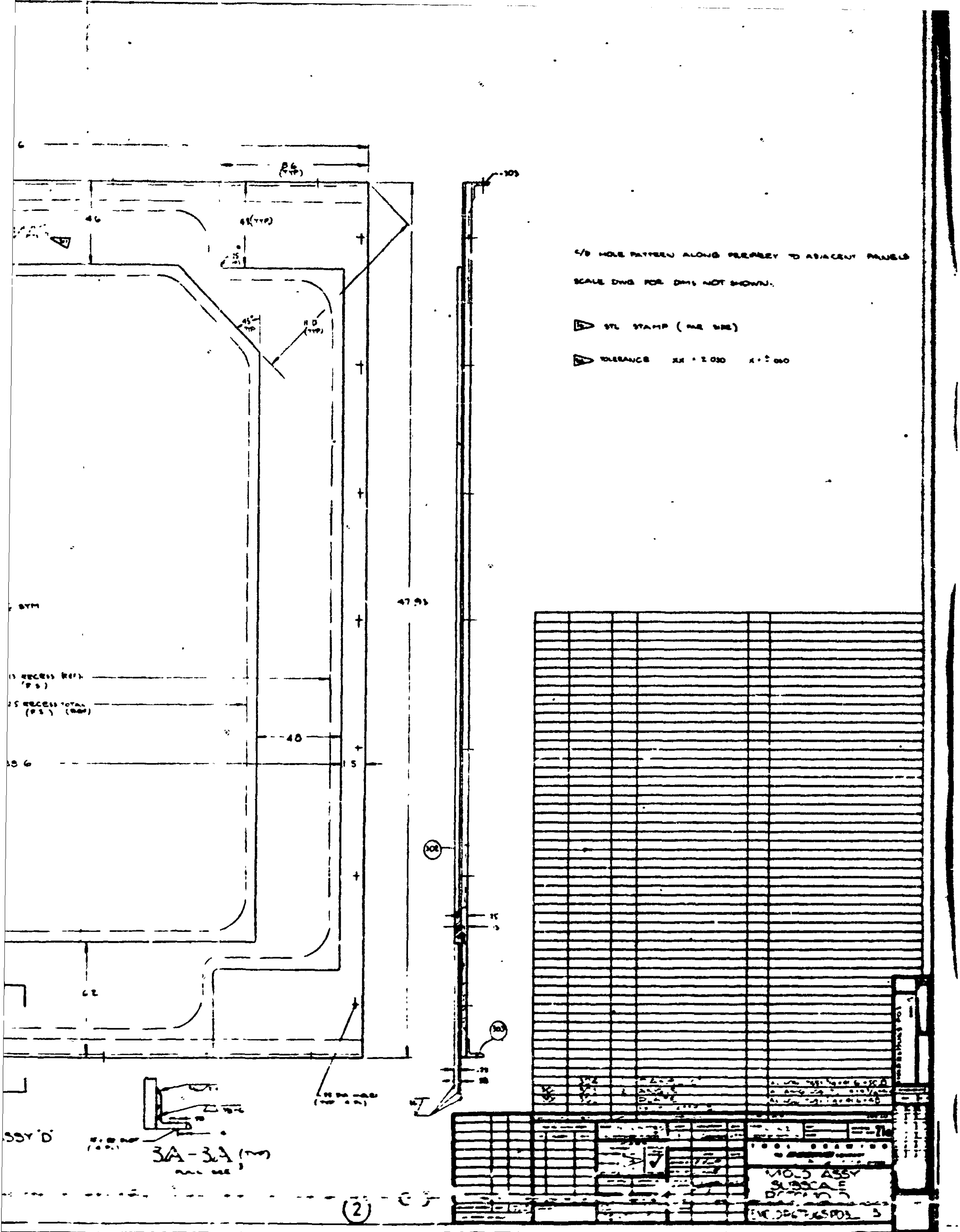
REMOVE BURR AFTER WELDING OUTSIDE WELDS UP TO EXCEED OUTSIDE DIM.



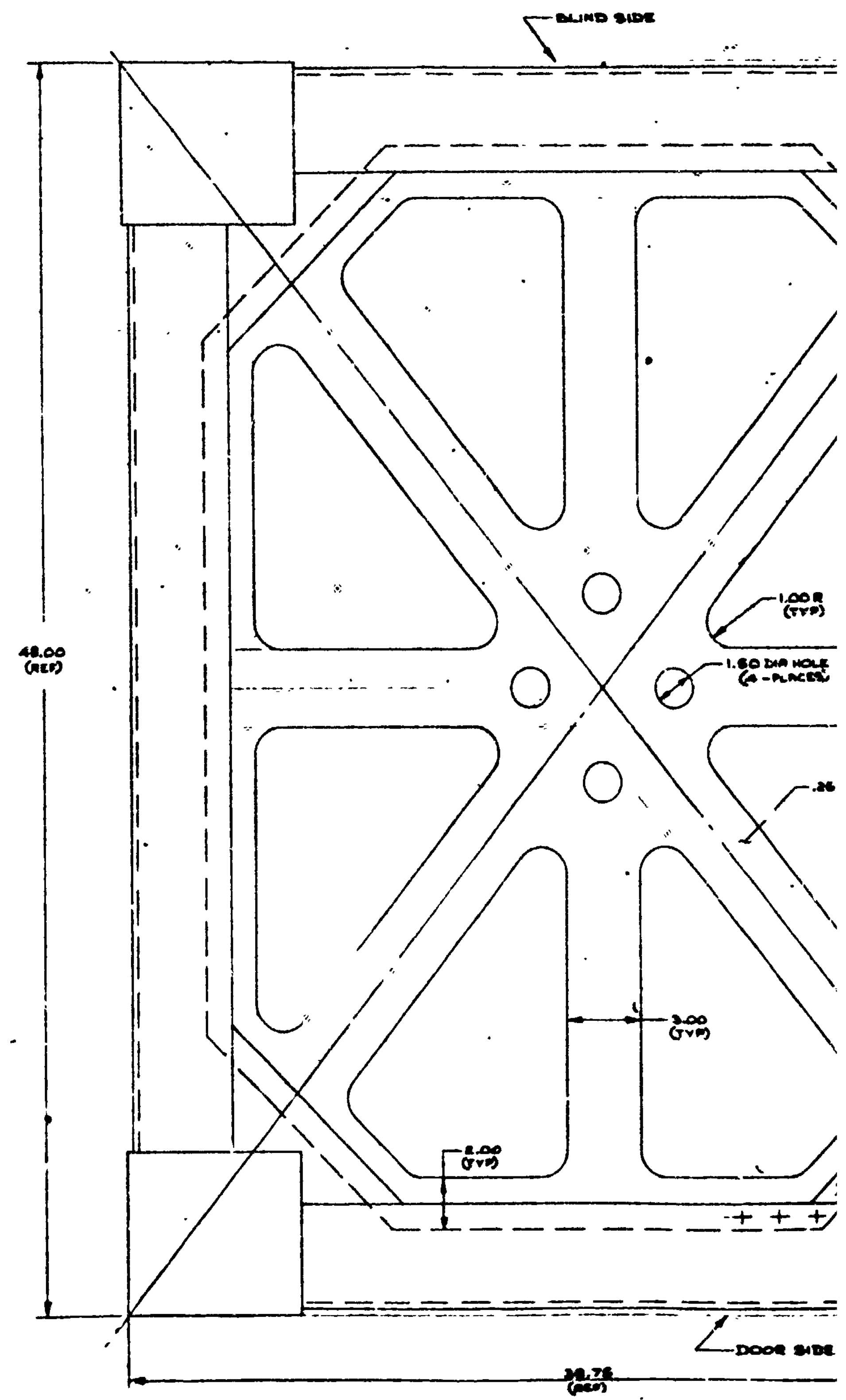


41.6
47.8
38.6
15 CRCESS (REF)
30 CRCESS (TOTAL) (REF)
45 (TYP)
45 (TYP)
15
PANEL 'C'

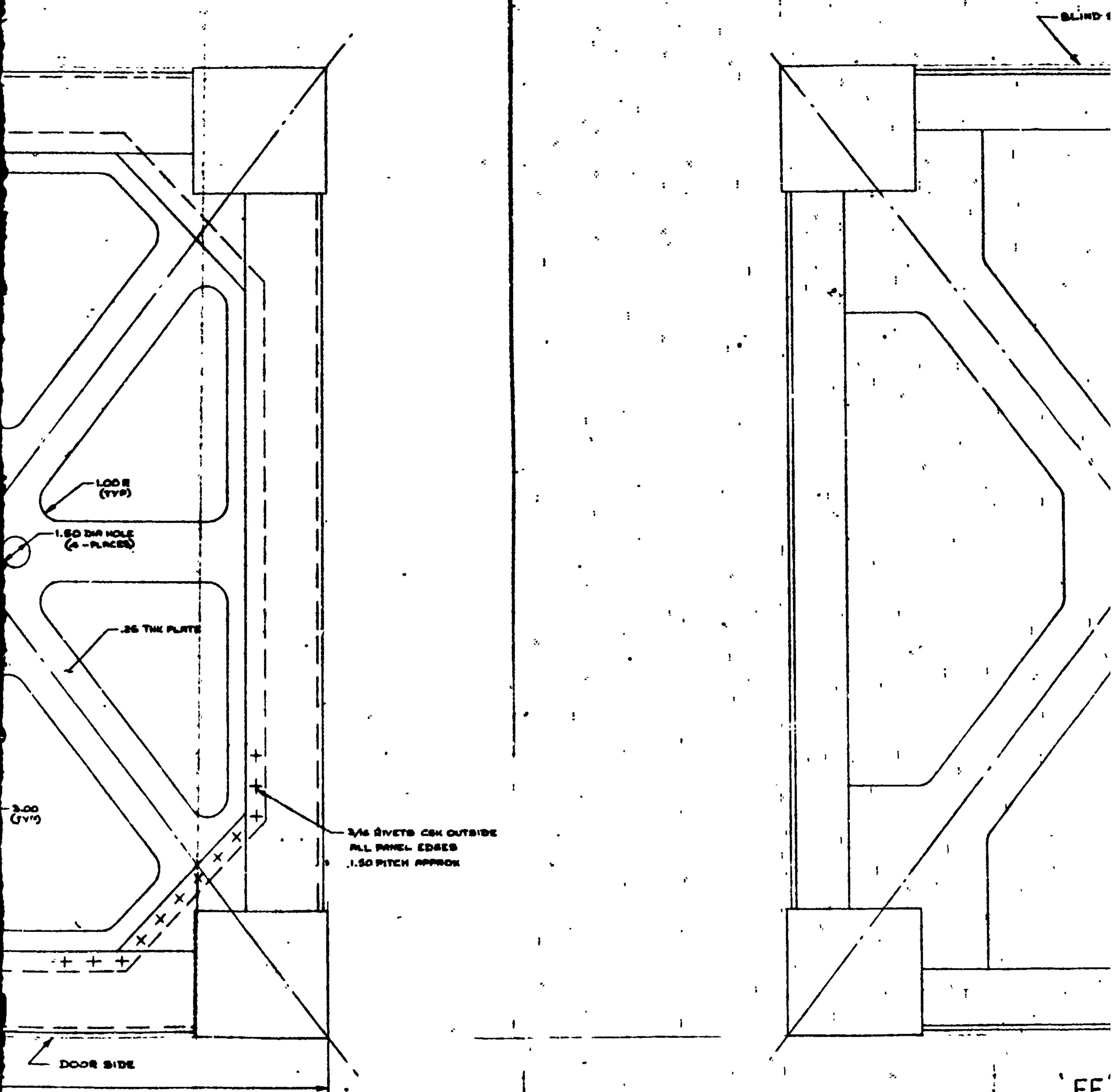

50.8
4.5 (TYP)
41.6
¢ SYM
55.6
3A
FANEL ASSY 'D'
5
4
3



SCALE DWG FOR DIMS NOT SHOWN.
STL STAMP
TOLERANCE
47.93
48
62
46
3A-3A
SSY 'D'
MOLD ASSY
SUBSCALE



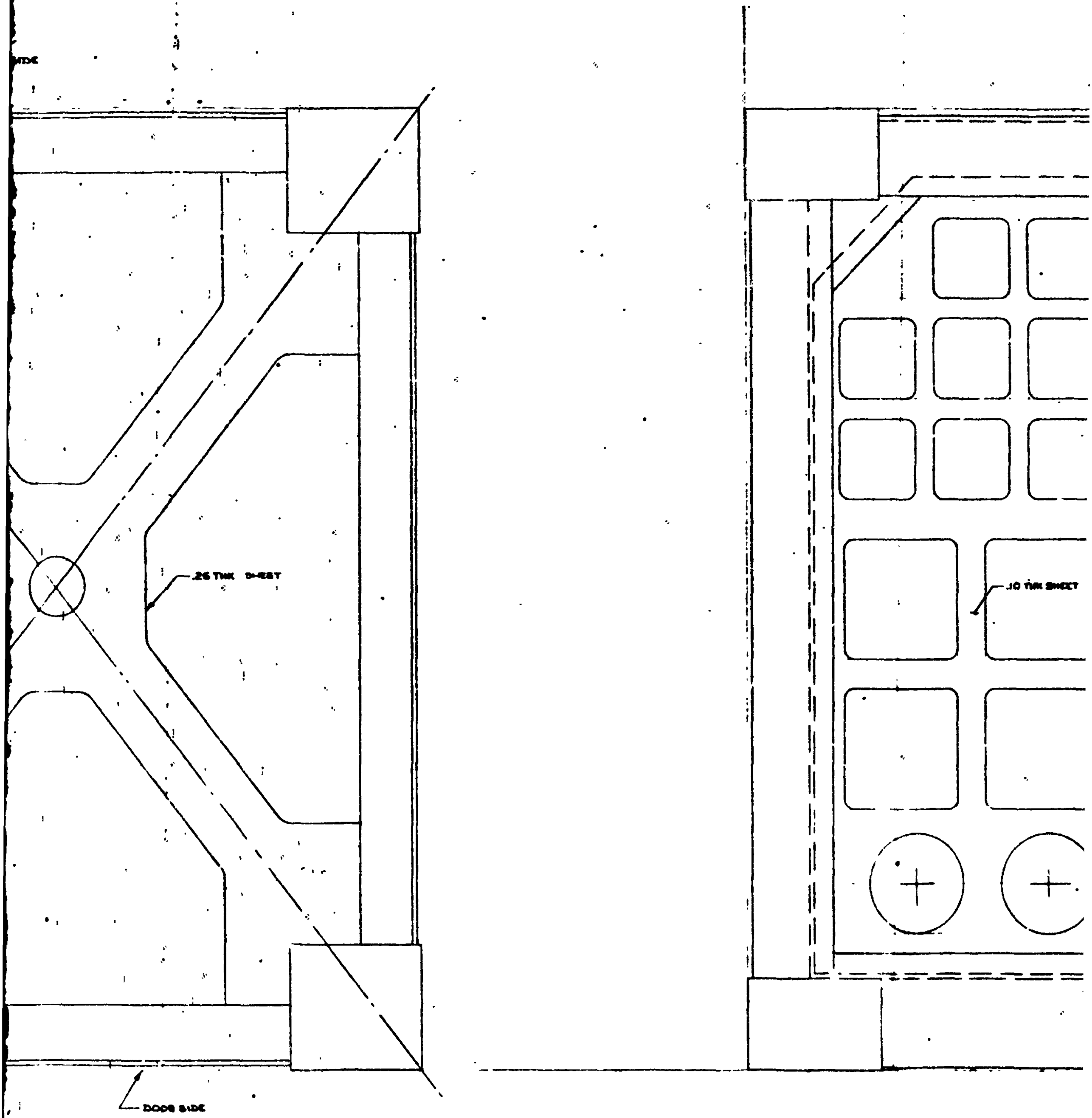
PANEL 'C'
ROOF SIDE
(SCALE - 1/2)



FF

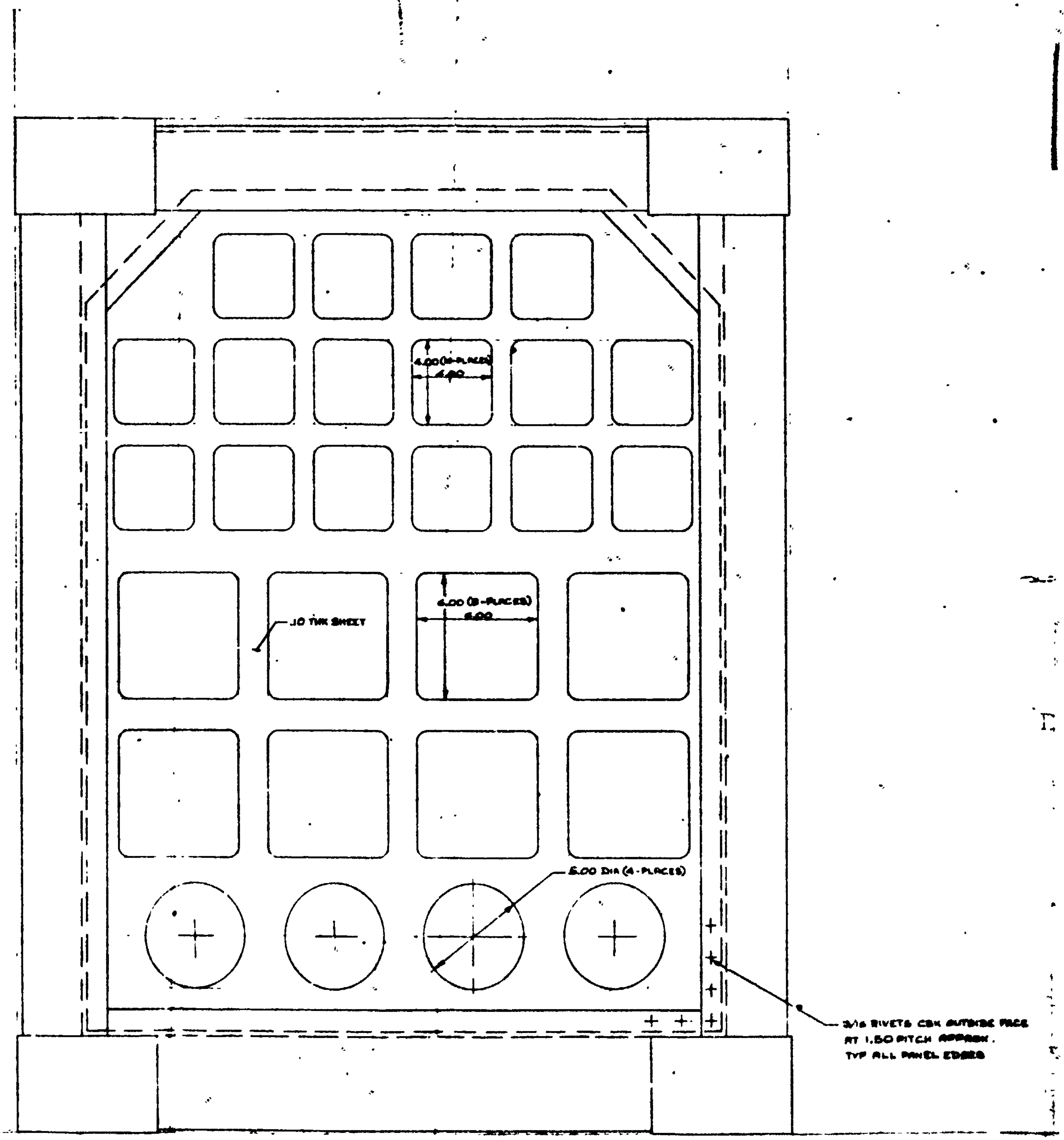
PANEL 'C' FL

(SCALE -



LOOR SIDE
1/2)

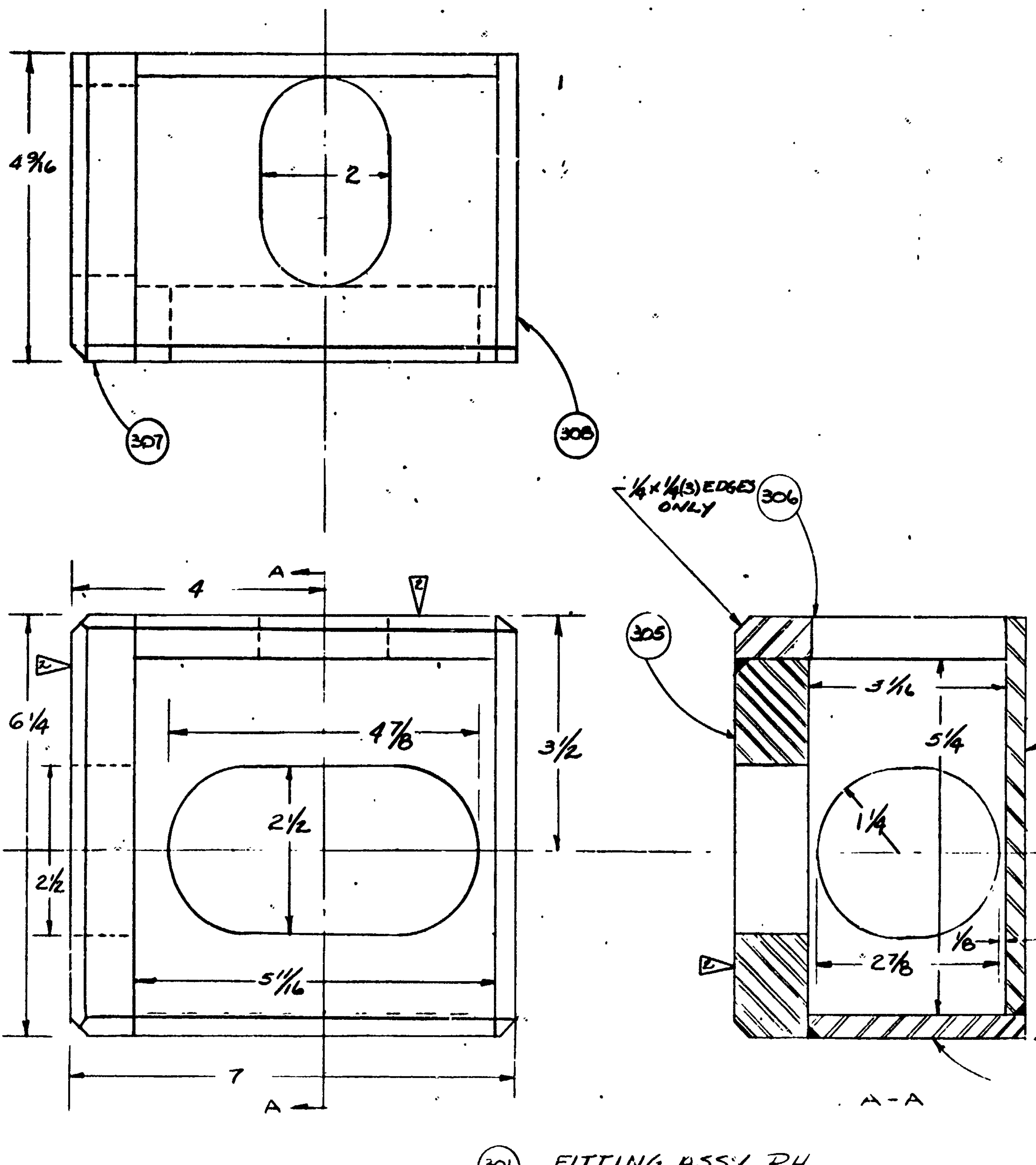
EI
PANEL 'D' I
(SCA



'EE'
PANEL 'D' BLIND SIDE
(SCALE – 1/2)

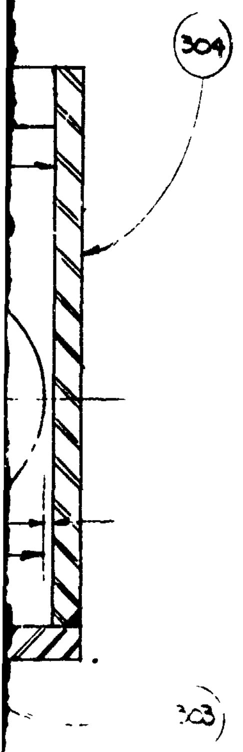
THE BOEING COMPANY
COMMERCIAL AIRPLANE CO. SEATTLE
STRUCTURE
ROTOMOLDED TRICON
CONTAINER
R677065P03

C-6



(301) FITTING ASSY RH

(302) LH OPP -1



NOTES

WELD APPROX 60% WELD PREP EDGES APPROX AS SHOWN
BREAK SHARP EDGES
SCALE DWG FOR DIM NOT SHOWN

1 ▷ 6061 T6 PLATE

2 ▷ THESE SUR[illegible] TO BE FLAT & NORMAL TO EACH OTHER

ASSY USED ON	DETAIL NO	QUANTITY	NAME OF DETAIL	ZONE	MATERIAL	STOCK SIZE
	308	1	[illegible]			1/2 X 4 1/2 X 6 1/2 1 ▷
	307	[illegible]	[illegible]			1 1/4 X 4 5/8 X 6 1/2
	306	1	[illegible]			3/4 X 4 3/16 X 5 11/16
	305	1	[illegible]			1 1/4 X 5 3/4 X 5 11/16
	304	1	[illegible]			3/8 X 6 X 5 11/16
	303	1	[illegible]			1/2 X 3 1/2 X 5 11/16 1 ▷
	302		[illegible]			
	301		[illegible]			

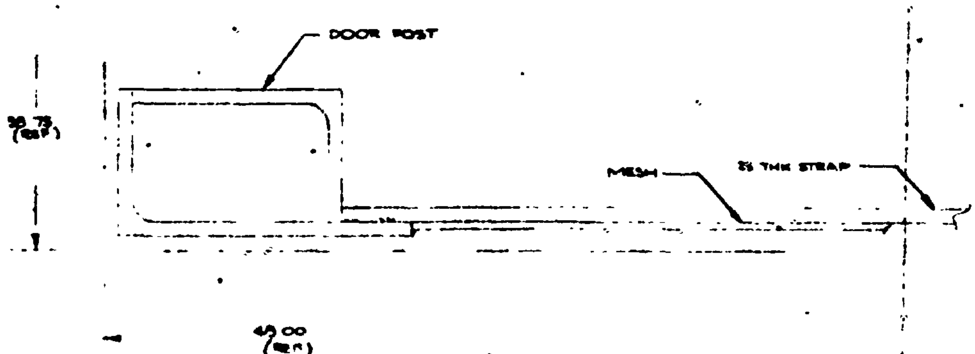
SCALE FULL
ALL DIMENSIONS IN INCHES
EXCEPT AS NOTED
TOLERANCE
FRACTIONAL ± 1/16
DECIMAL ± —
ANGULAR ± —
MACHINE FINISH ✓

FINISH
COLOR OR PROTECTIVE
SECT
MODEL TEST
DRAWING SHEET SIZE 5

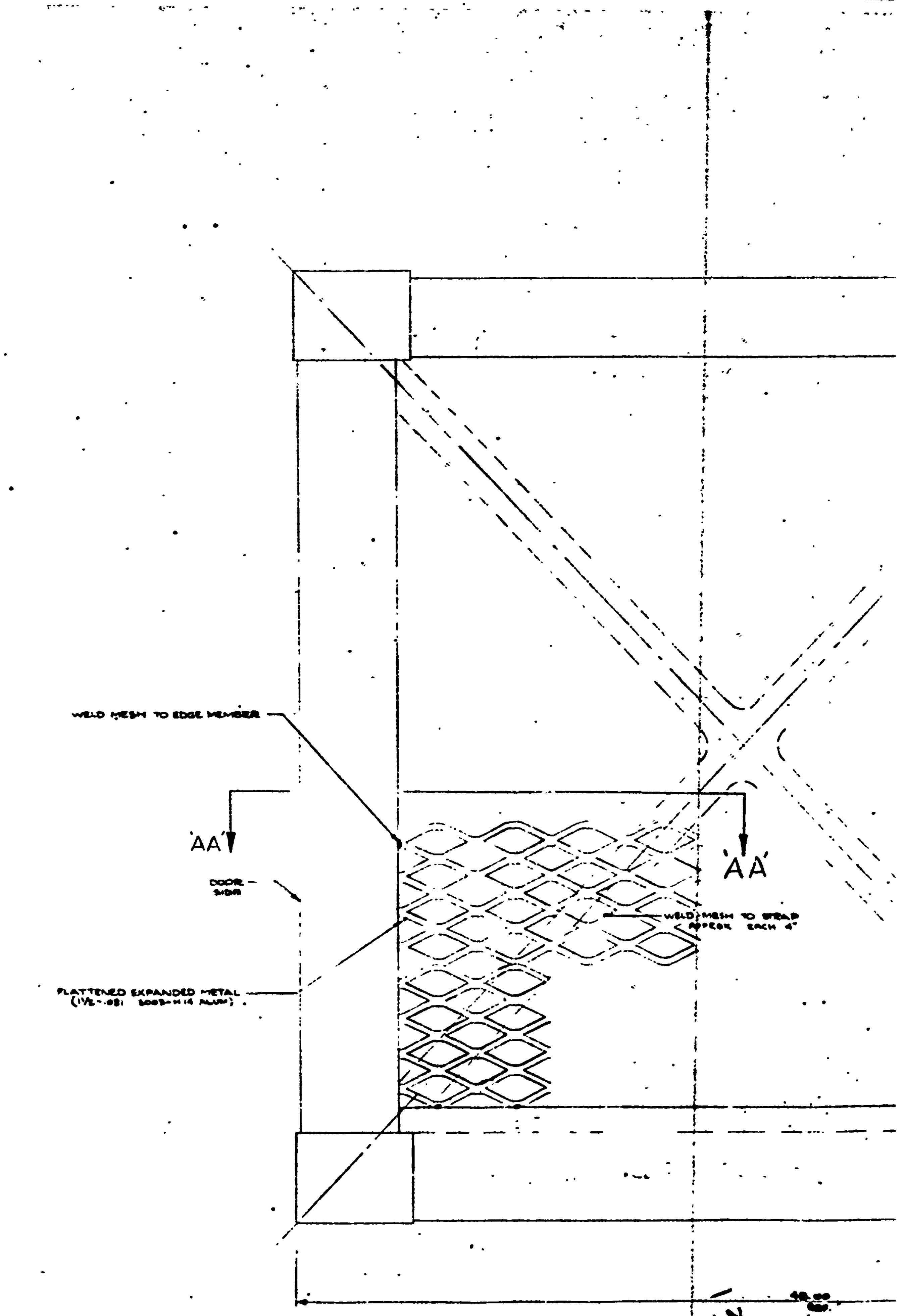
TOOL DRAWING
THE BOEING COMPANY
CAG LTN DIVISION

FITTING
SUB-SCALE CONT.

R617065 P03 SHEET 3

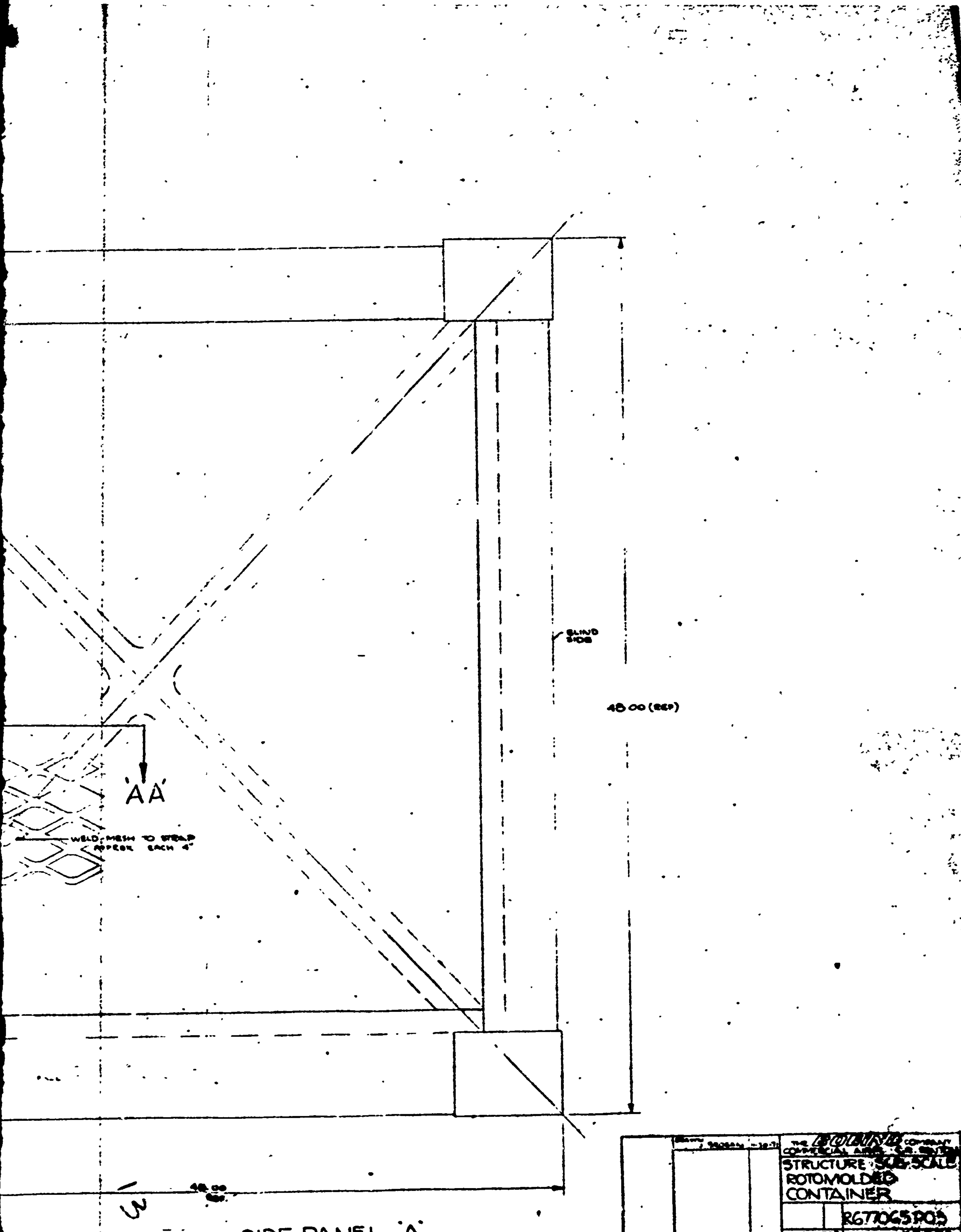


'AA' (1/1 SCALE)



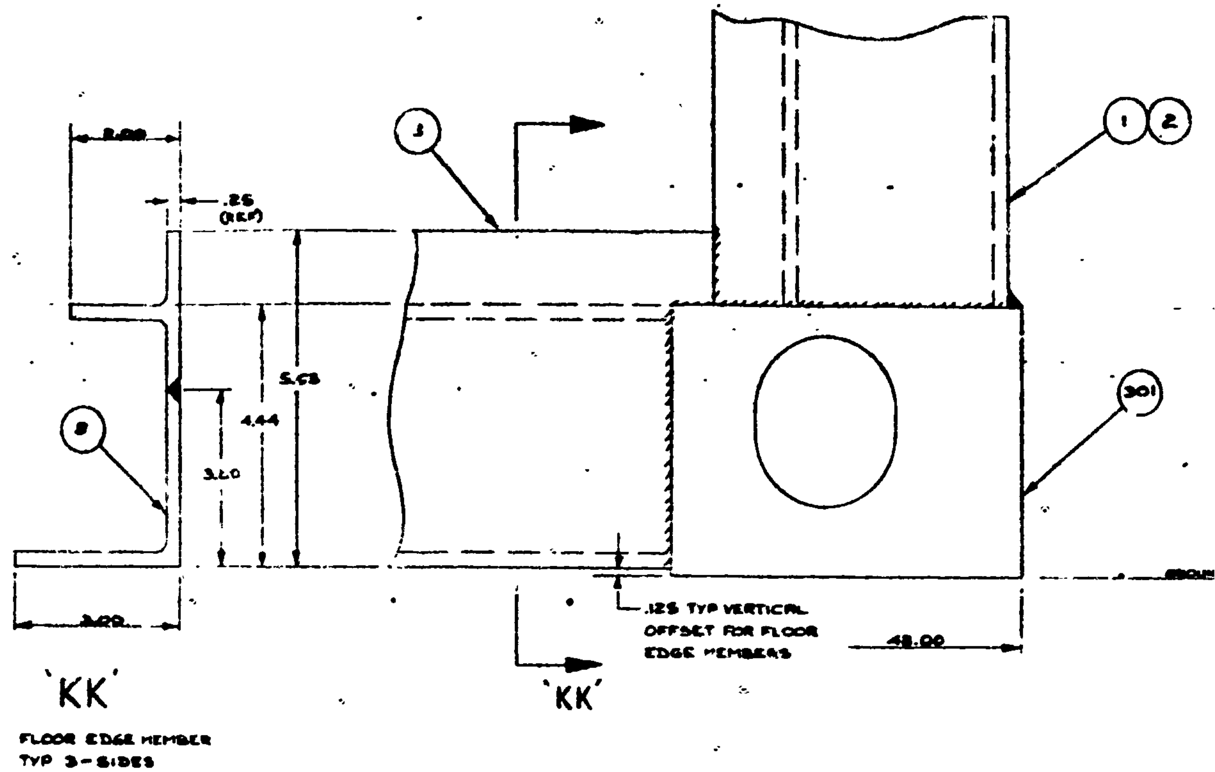
SIDE PANEL - TRICON SUB-SCALE
(FLATTENED EXPANDED METAL)

SIDE

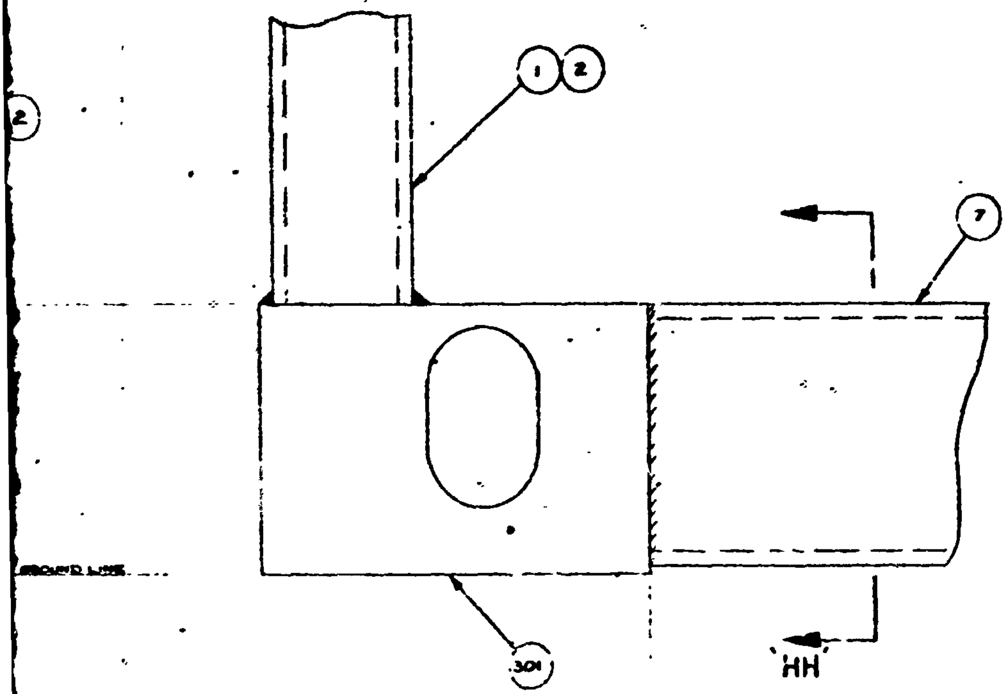


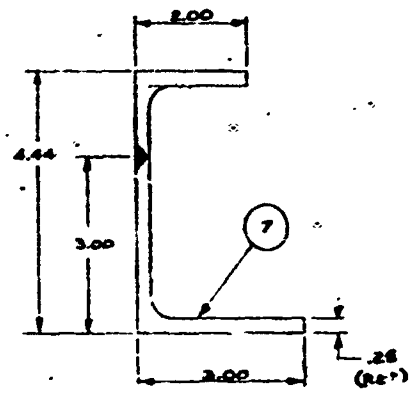
SIDE PANEL 'A'
(SCALE - ½)

273



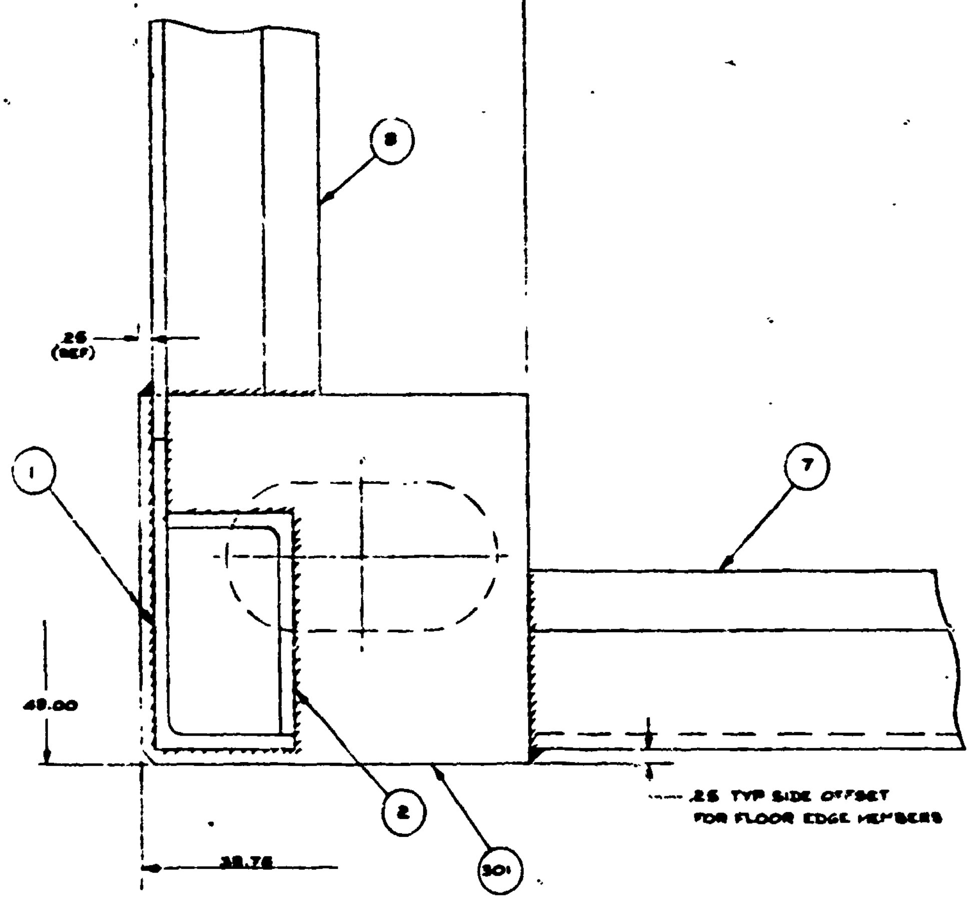
DETAIL V
(SCALE -1/1)

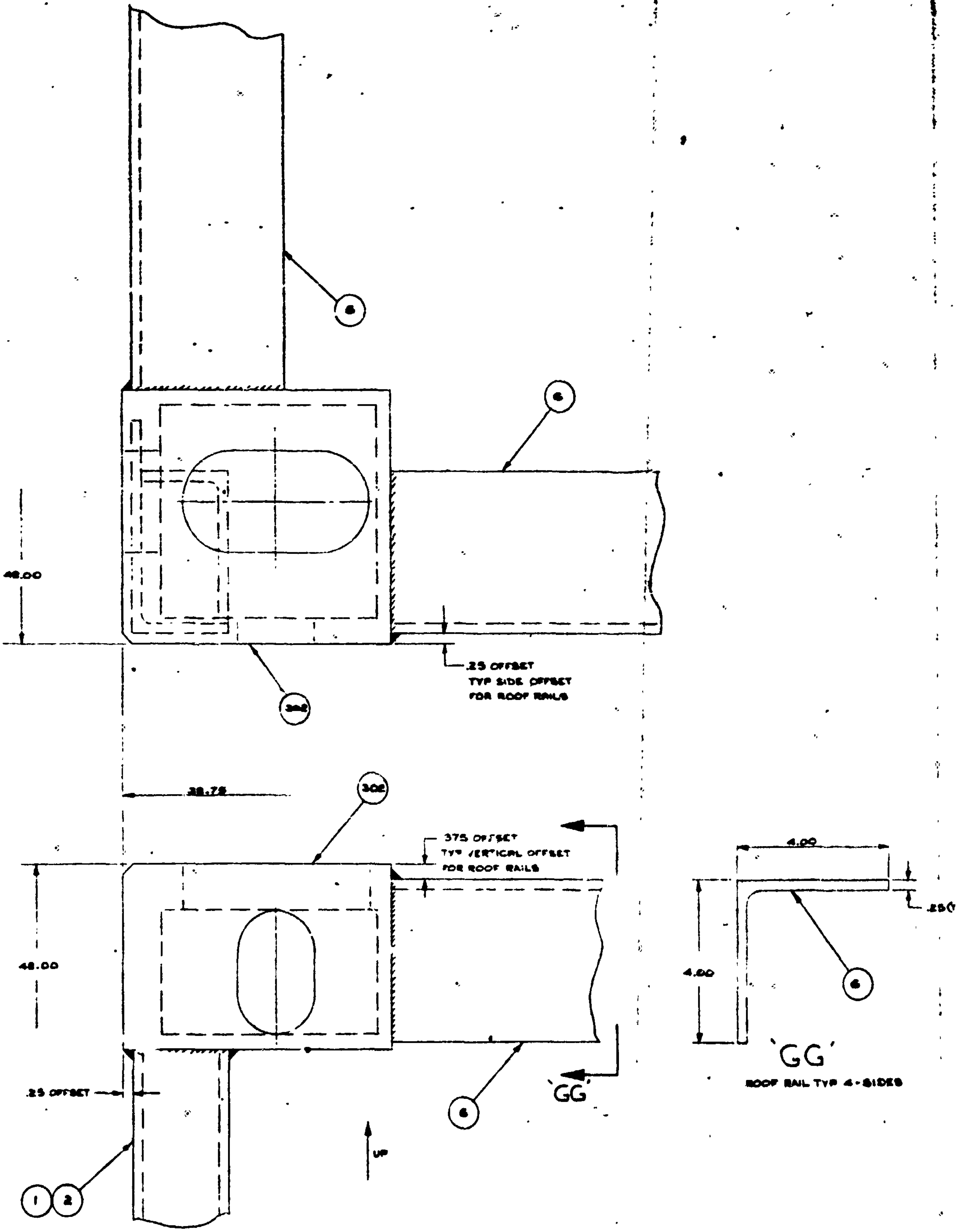




'HH'

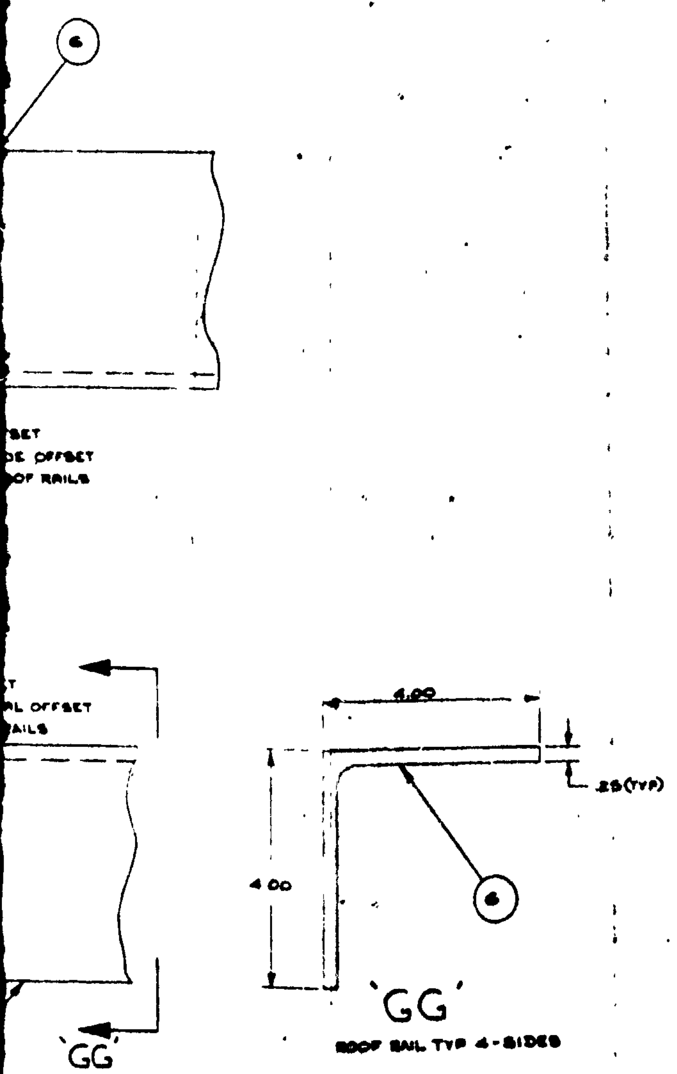
FLOOR EDGE MEMBER DOOR SIDE



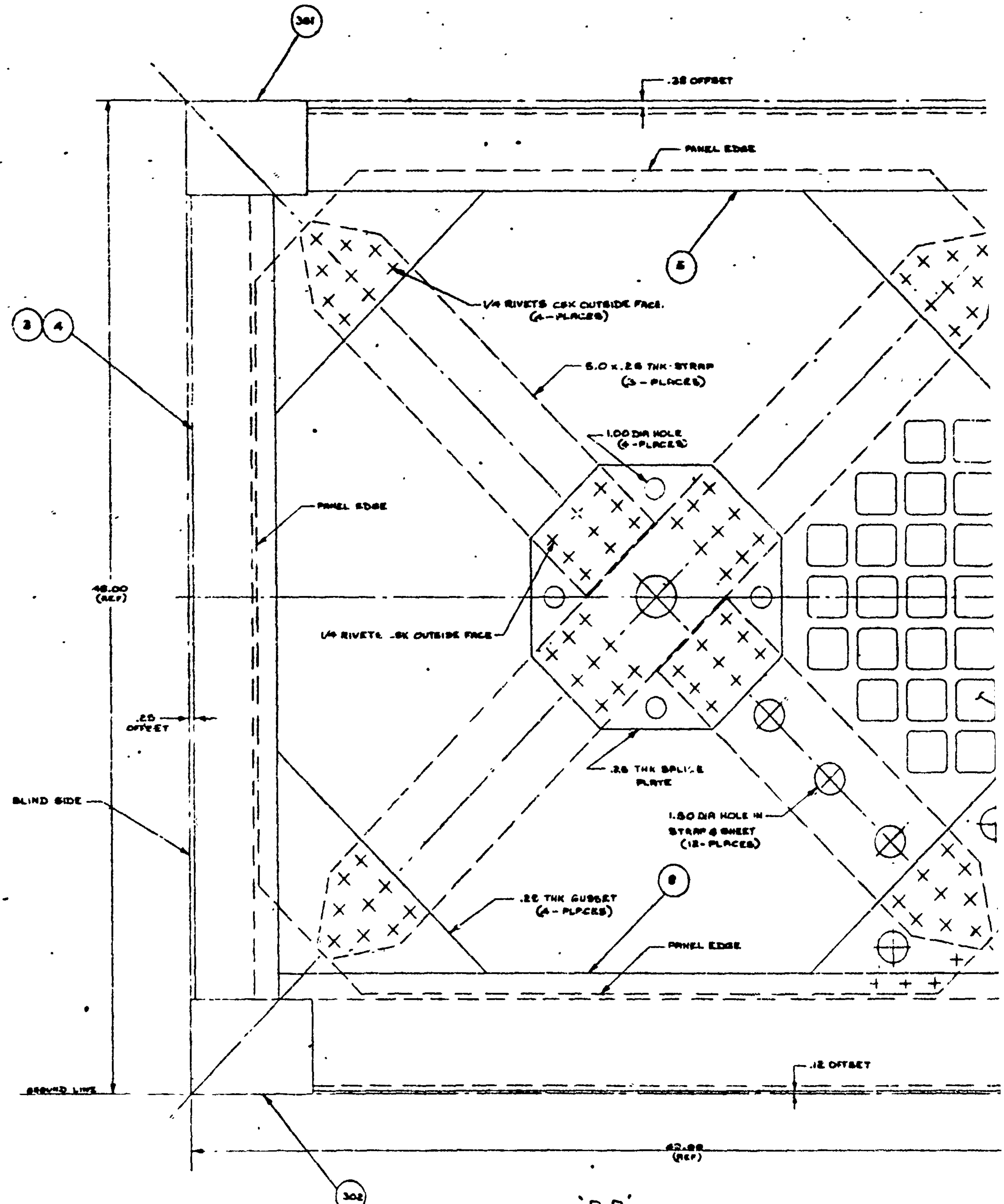


DETAIL IV

(SCALE - 1/1)



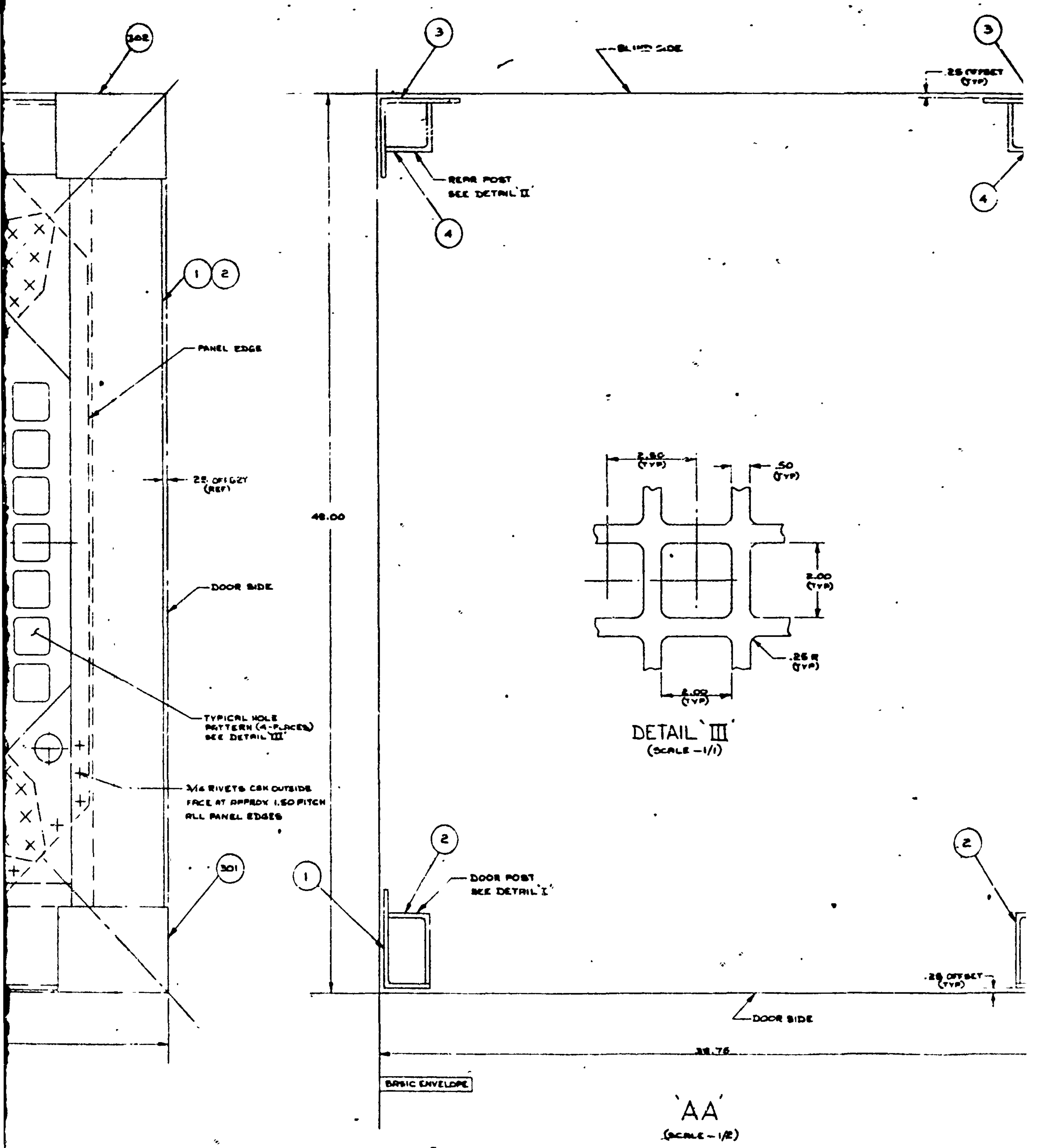
USED ON	DRAWN J. BROGAN	DATE	THE BOEING COMPANY COMMERCIAL AIRPLANE ... SEATTLE WASH
	CHECKED		STRUCTURE SUB-SCALE
SECT NO	STRESS		ROTOMOLDED CONT.
CHG NO	ENGR J. BROGAN		
GROUP CODE	GROUP		CODE IDENT NO 81205 J R677065P03
HE&D	PROJ		SCALE 1/1



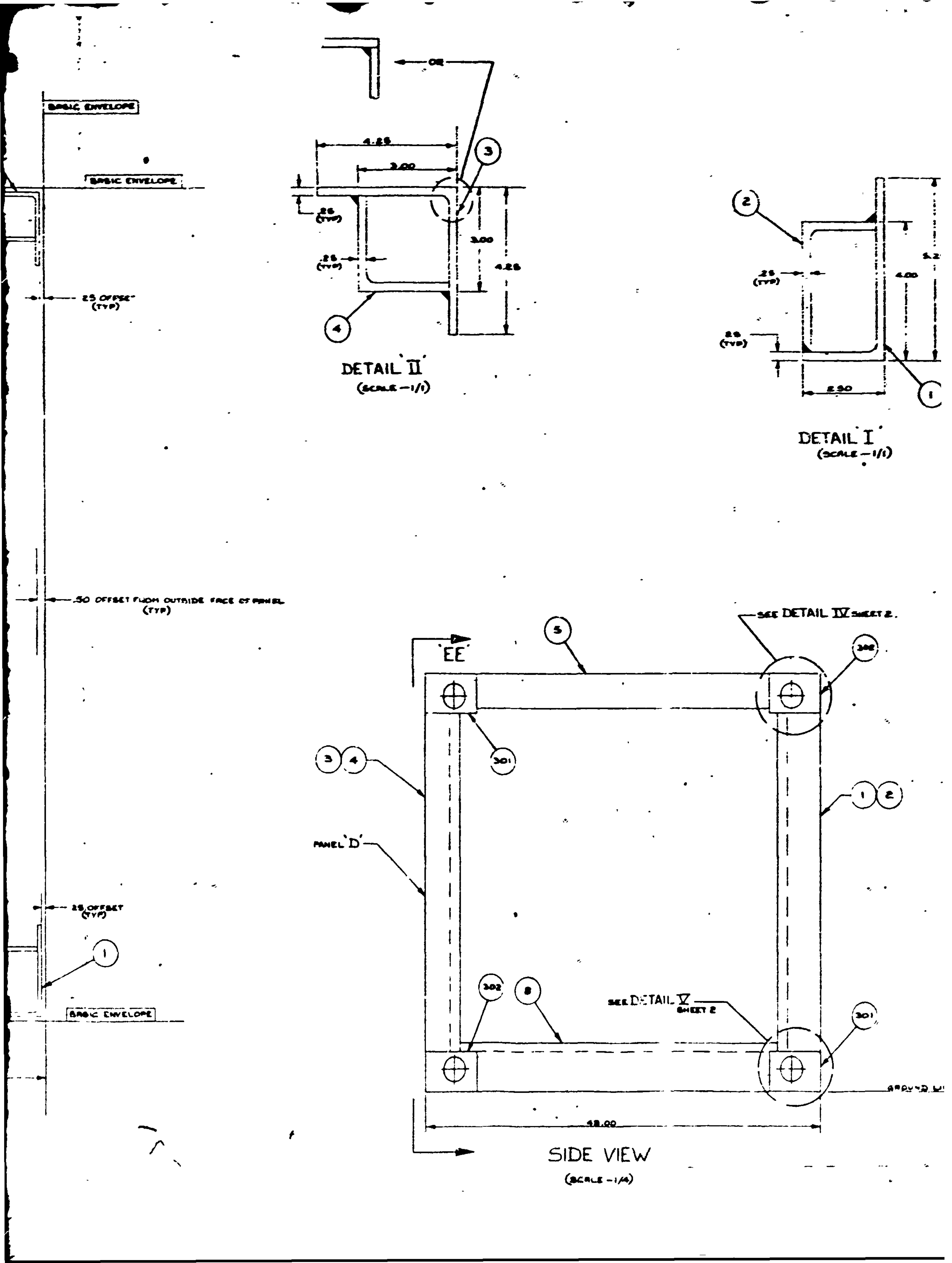
'BB'

SIDE PANEL 'B'

(SCALE - 1/2)



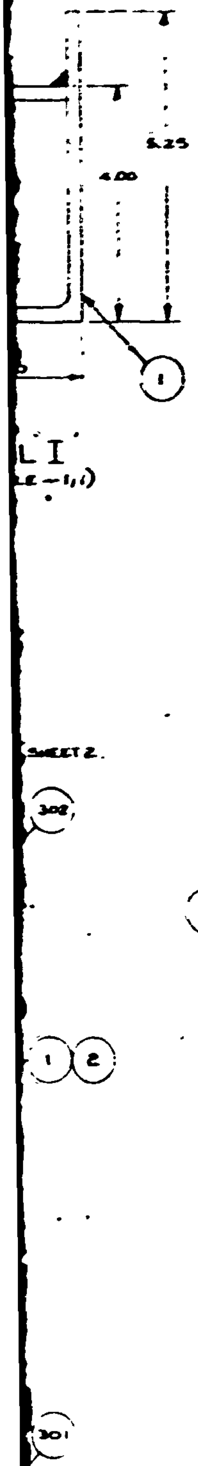
BLIND SIDE
.25 OFFSET (TYP)
REAR POST
SEE DETAIL 'II'
PANEL EDGE
.25 OFFSET (REF)
48.00
DOOR SIDE
2.50 (TYP)
.50 (TYP)
2.00 (TYP)
.25 R (TYP)
2.00 (TYP)
DETAIL 'III'
(SCALE -1/1)
TYPICAL HOLE PATTERN (4-PLACES) SEE DETAIL 'III'
3/16 RIVETS CSK OUTSIDE FACE AT APPROX 1.50 PITCH ALL PANEL EDGES
DOOR POST
SEE DETAIL 'I'
.25 OFFSET (TYP)
DOOR SIDE
BASIC ENVELOPE
'AA'
(SCALE - 1/2)

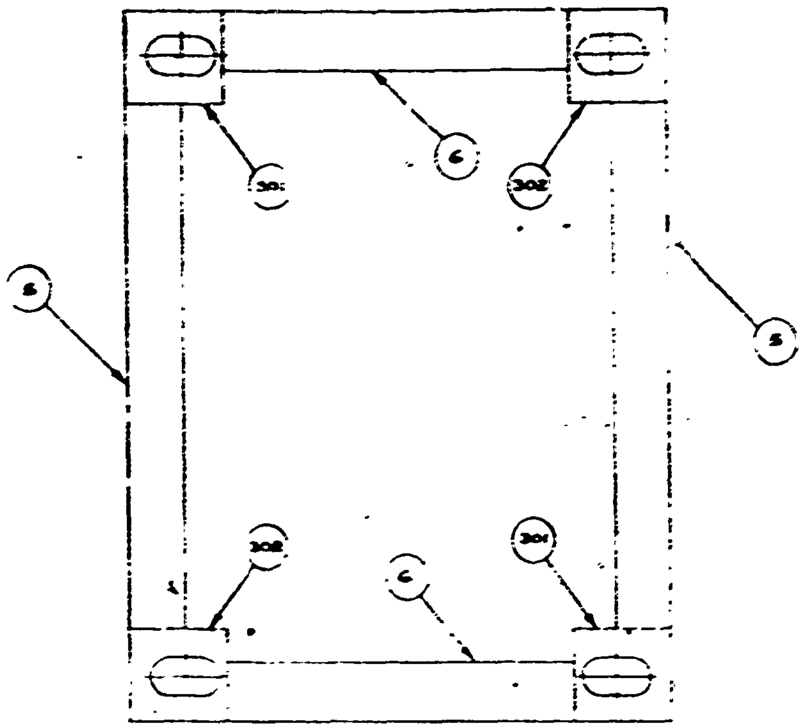


DETAIL 'II'
(SCALE – 1/1)

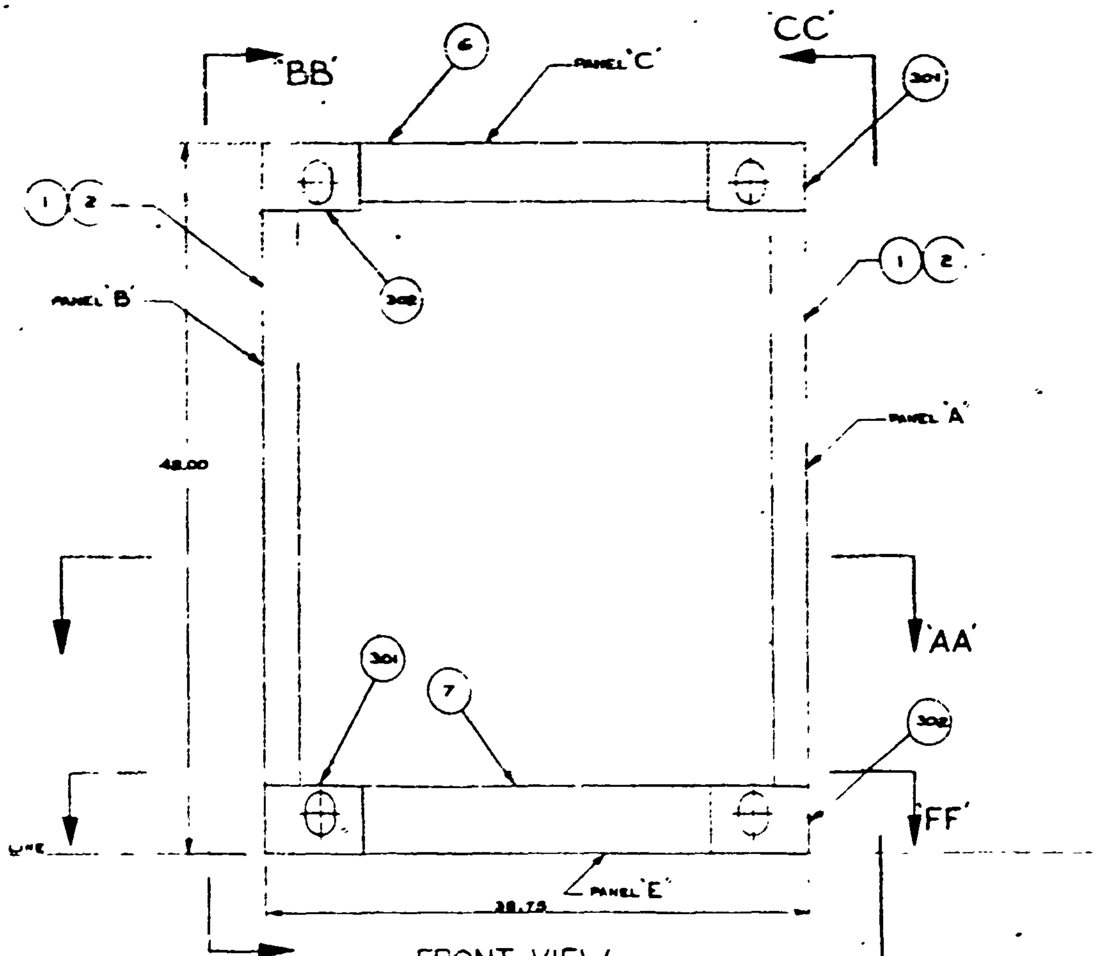
DETAIL 'I'
(SCALE – 1/1)

SIDE VIEW
(SCALE – 1/4)

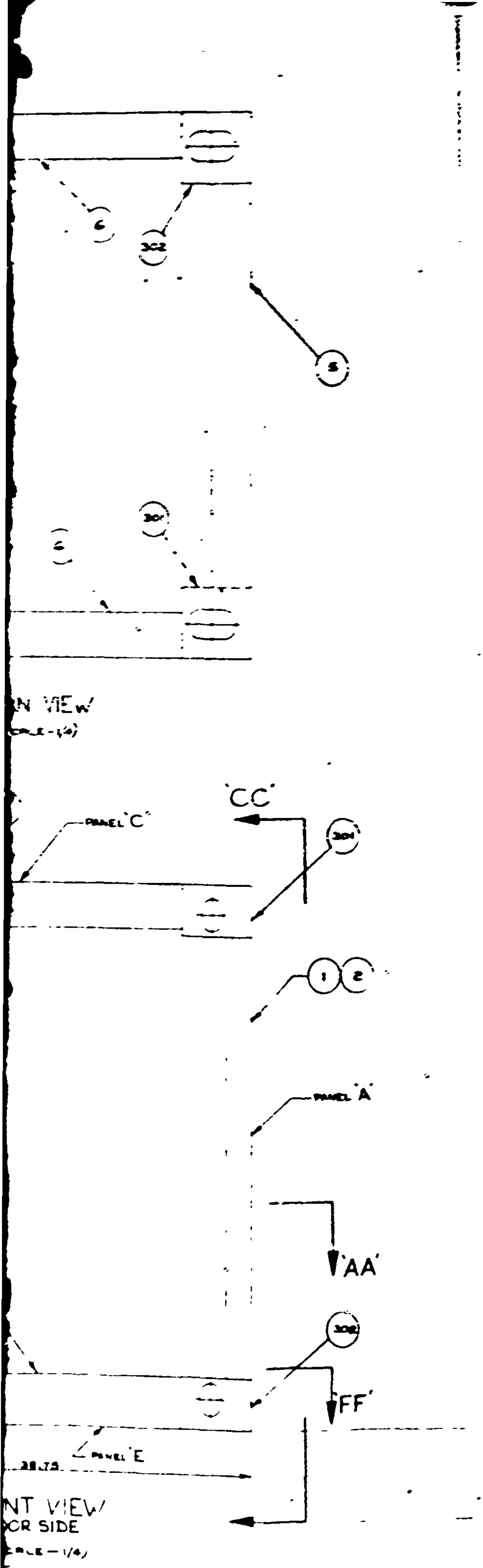




PLAN VIEW
(SCALE - 1/4)



FRONT VIEW
DOOR SIDE
(SCALE - 1/4)



NOTE —

INDICATES [illegible] FILLET WELD

SCALE DWG FOR DIMENSIONS NOT SHOWN

ANGLE — 6061-T6

TEE — [illegible]

6061-T6

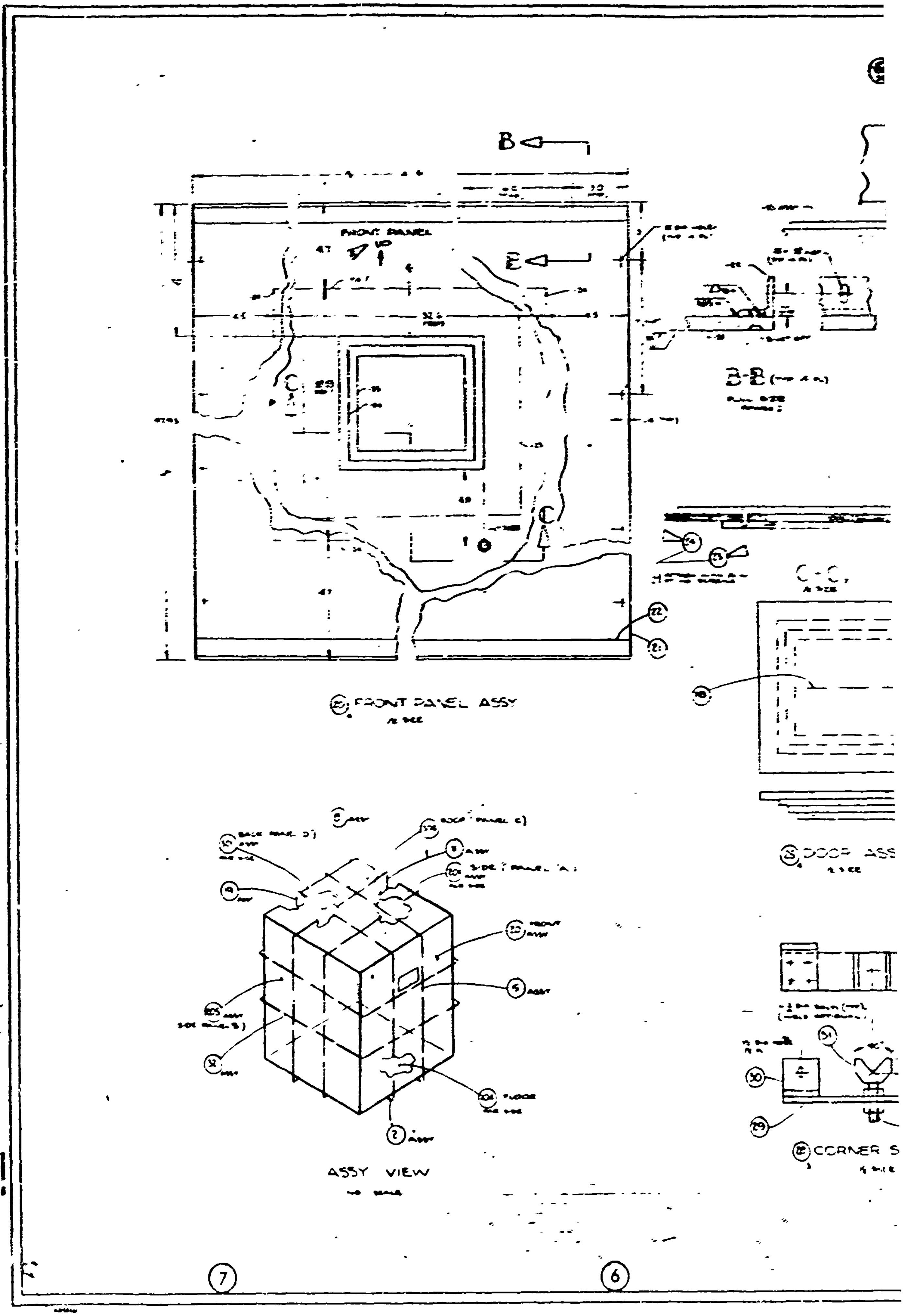
	302	4	CORNER FTG — OPP 301		
	301	4	CORNER FTG		
	9	1	FLOOR EDGE MBR - REAR	[illegible]	
	8	2	FLOOR EDGE MBR - SIDE	[illegible]	
	7	1	FLOOR EDGE MBR - FRONT	[illegible]	
	6	2	ROOF RAIL	[illegible] x 25 ANGLE	
	5	2	ROOF RAIL	4 x 4 x 1/4 x 36½ ANGLE	
	4	2	REAR POST	3 x 3 x 1/4 x 30 ANGLE	
	3	2	REAR POST	[illegible]	
	2	2	DOOR POST	4 x 4 x 1/4 x 30 ANGLE	
	1	2	DOOR POST	[illegible]	
ITEM / DASH NO.	DETAIL NO.	QUAN	NAME OF DETAIL	SIZE	MATERIAL

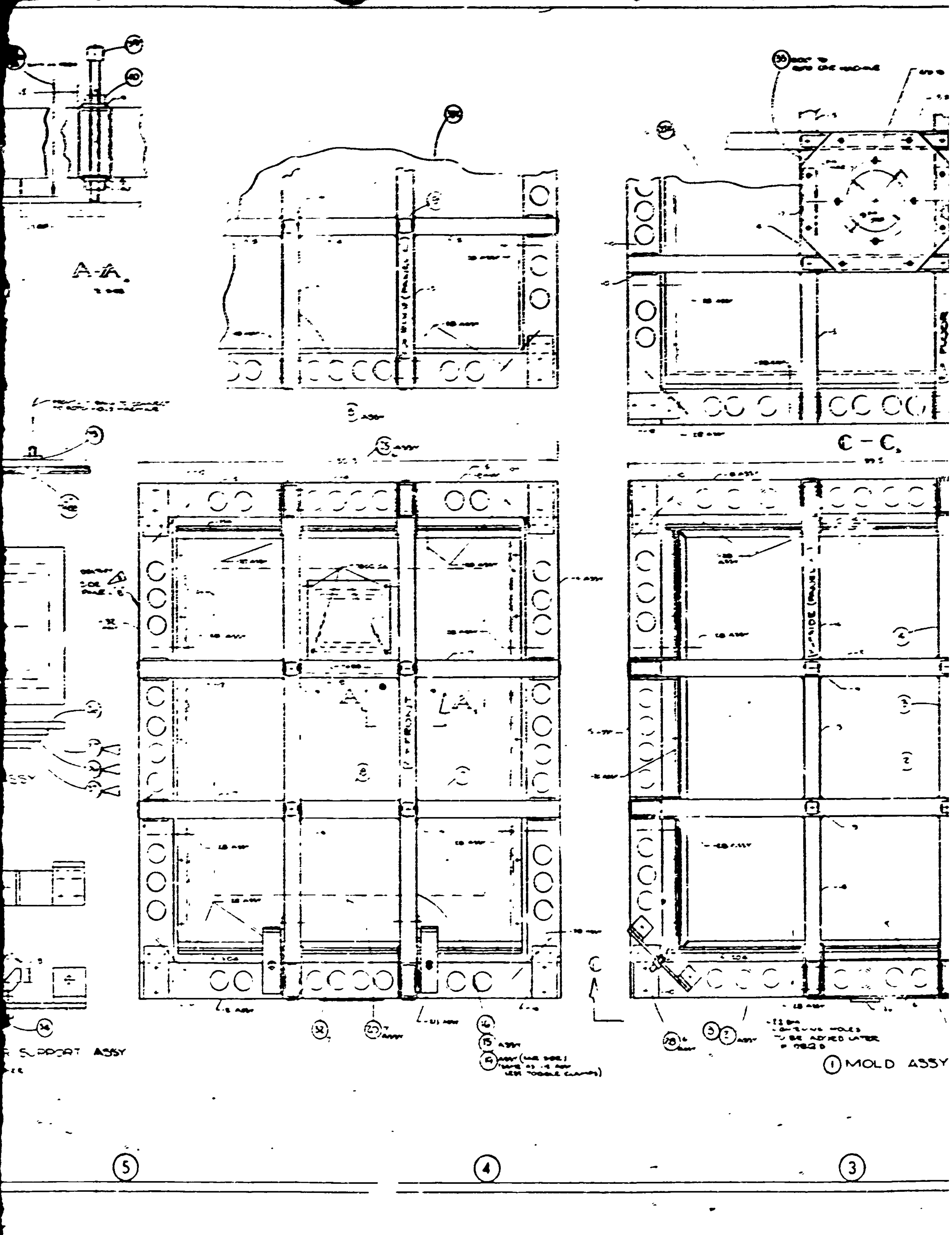
STRUCTURE SUB-SCALE
ROTOMOLDED CONT.

R677065PO3

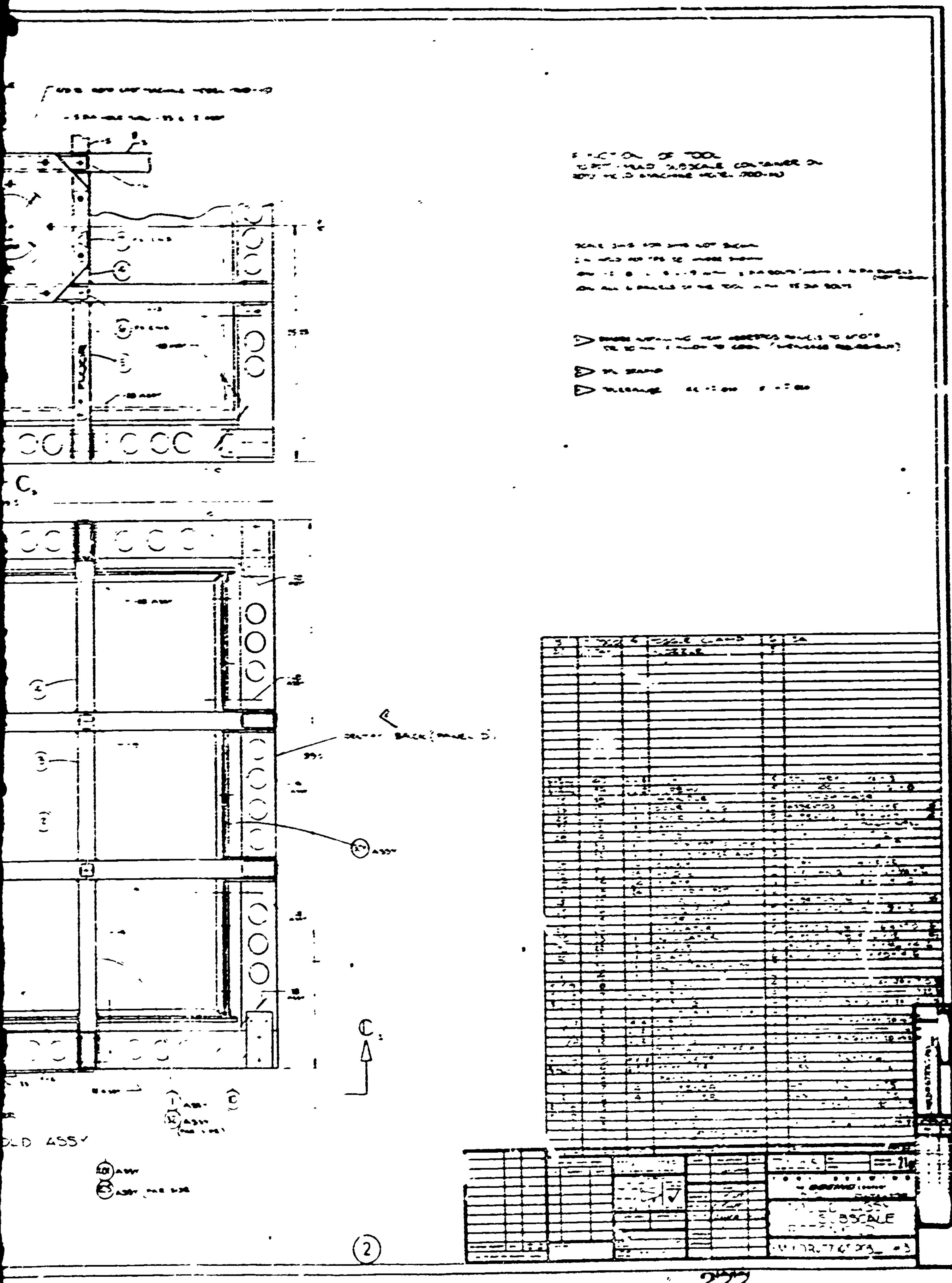
APPENDIX D

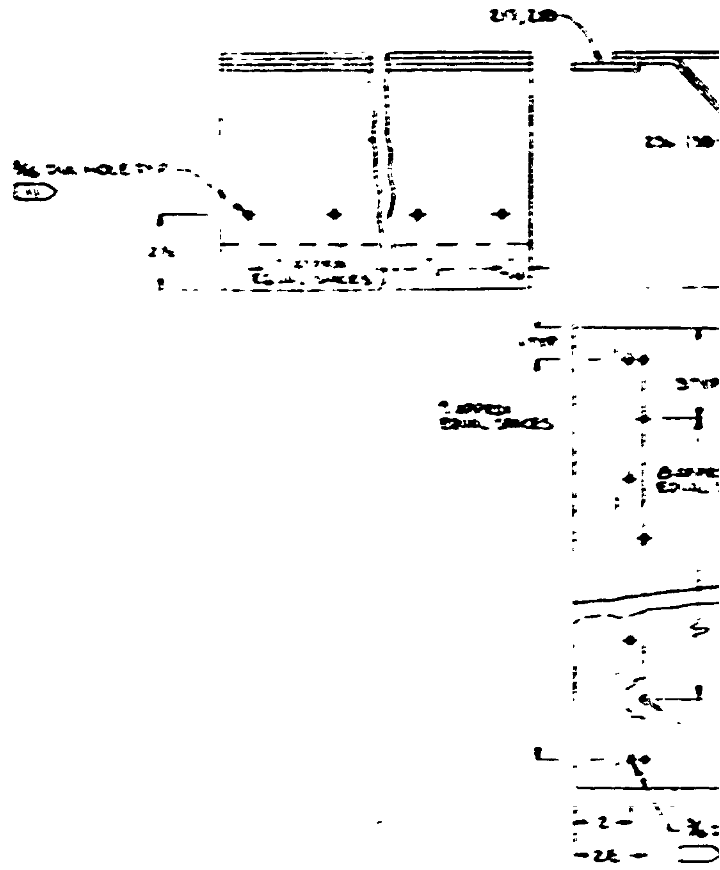
ENGINEERING DRAWINGS OF ALUMINUM SUBSCALE TRI CON CONTAINER AND MOLD


B
FRONT PANEL
B-B
C-C
FRONT PANEL ASSY
DOOR ASS
ASSY VIEW
NO SCALE
CORNER S
7
6



A-A
C - C
SUPPORT ASSY
MOLD ASSY
5
4
3

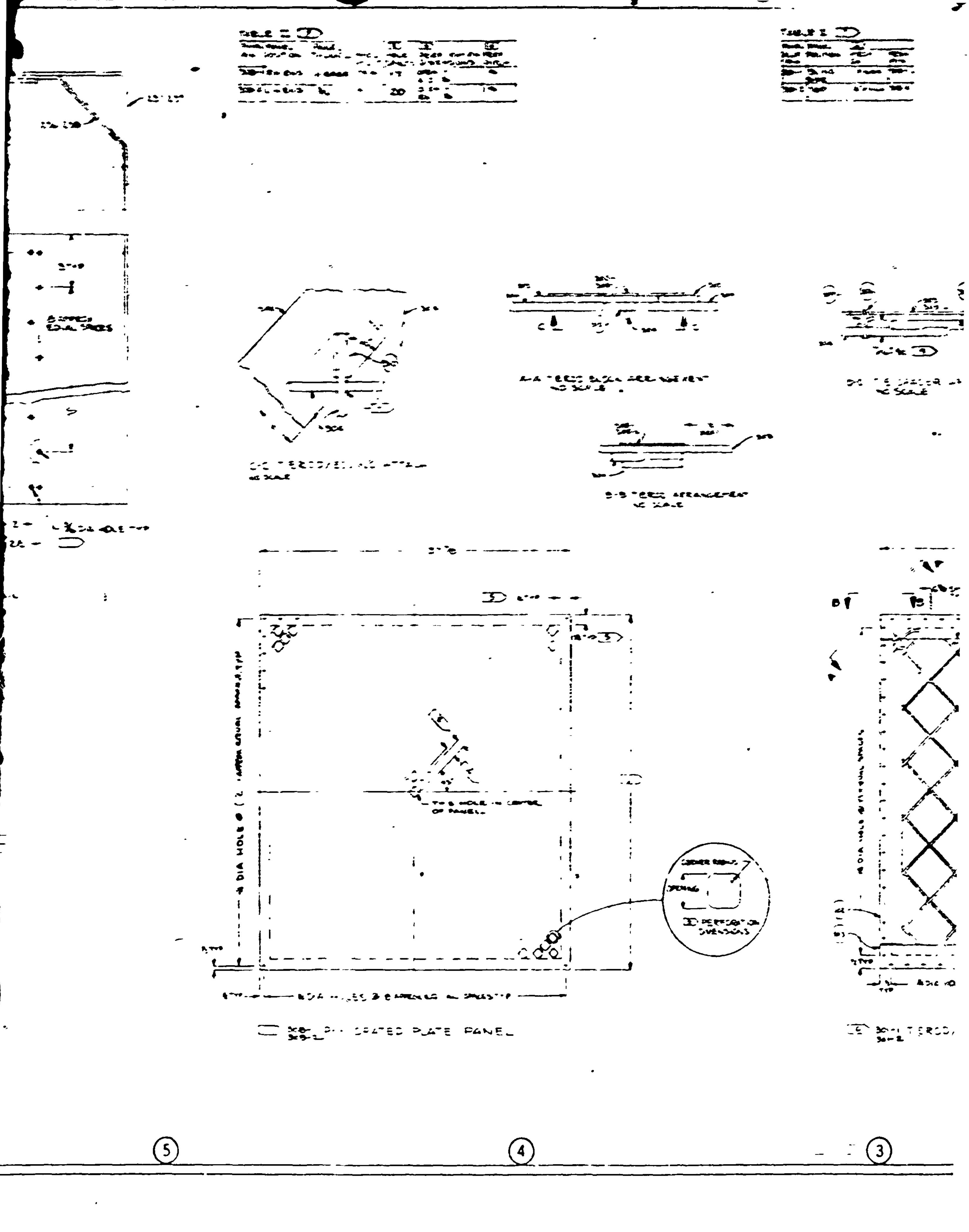

OLD ASSY
SUBSCALE
2



POST/RAIL FASTENING DETAIL
SCALE ½

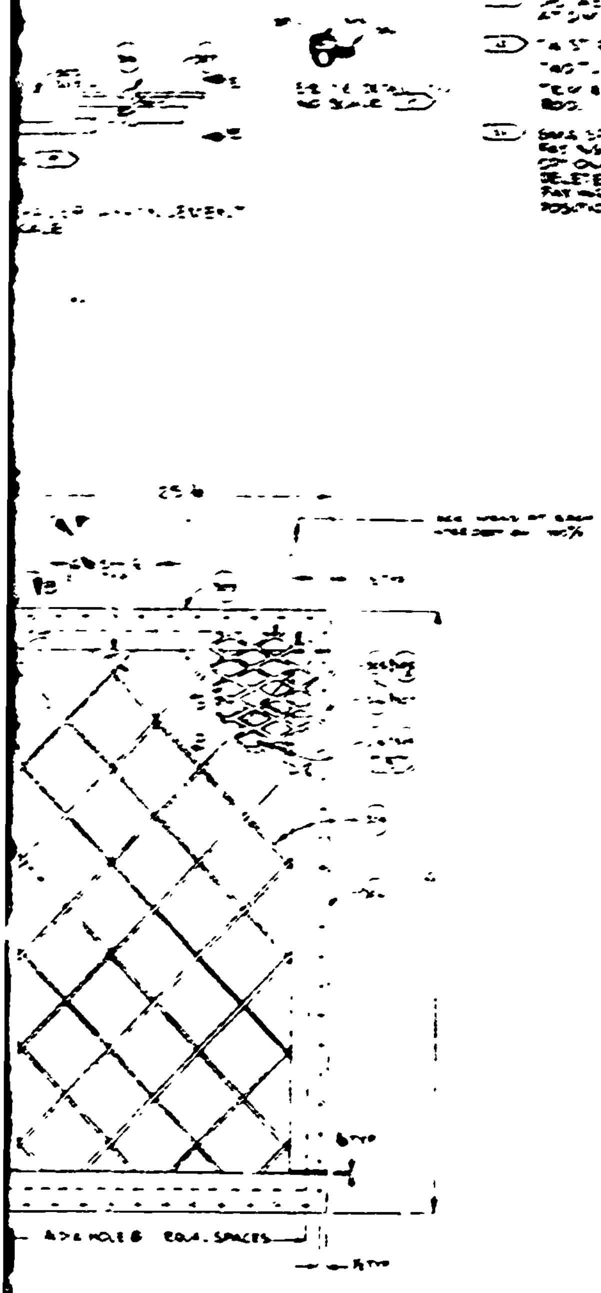
7

6



TYP HOLE IN CENTER OF PANEL
PERFORATION DIMENSIONS
PLATE PANEL
NO SCALE
5
4
3

1. SEE TABLE [illegible]
2. SEE TABLE I FOR HOLE SPACES
3. [illegible]
4. PERFORATION [illegible] SEE TABLE I FOR DIMENSIONS
5. [illegible]
6. SEE TABLE [illegible]
7. [illegible]
8. [illegible]
9. [illegible]
10. [illegible] TWO TURNS AT SIDE OF SPACER [illegible]
11. [illegible] SURFACE [illegible] POSITIONS SHOWN



[illegible] MESH PANEL ASSY

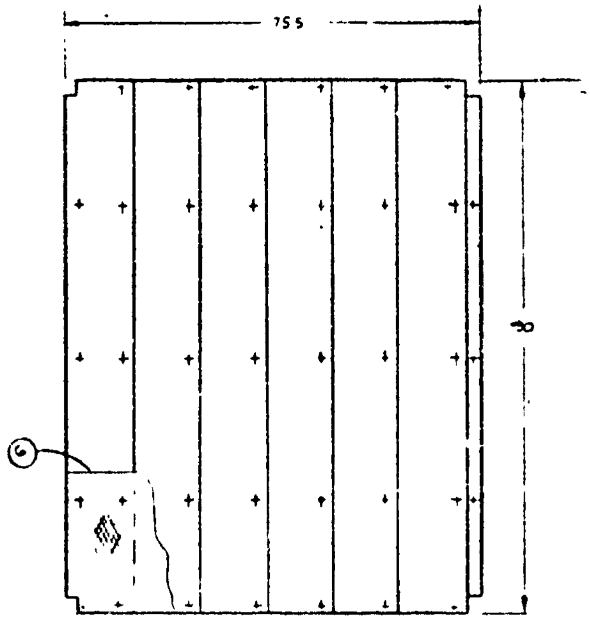
TOOL DRAWING

BOEING

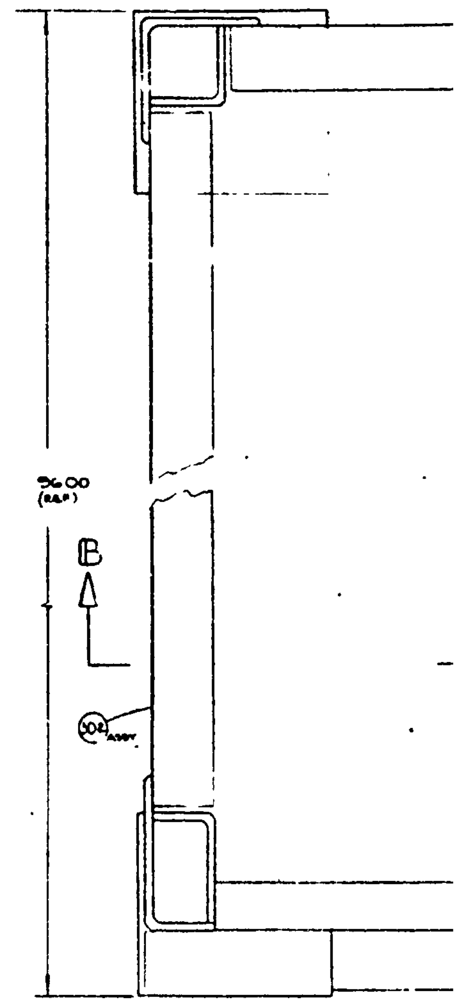
(2)

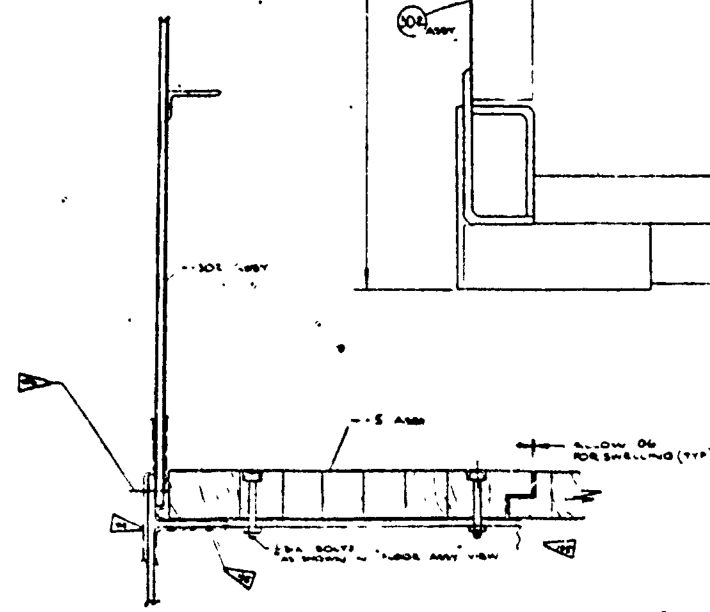
APPENDIX E

ENGINEERING DRAWING AND DESIGN CALCULATIONS FOR FULL SIZE TRICON CONTAINER



(5) FLOOR ASSY
1/10 SIZE

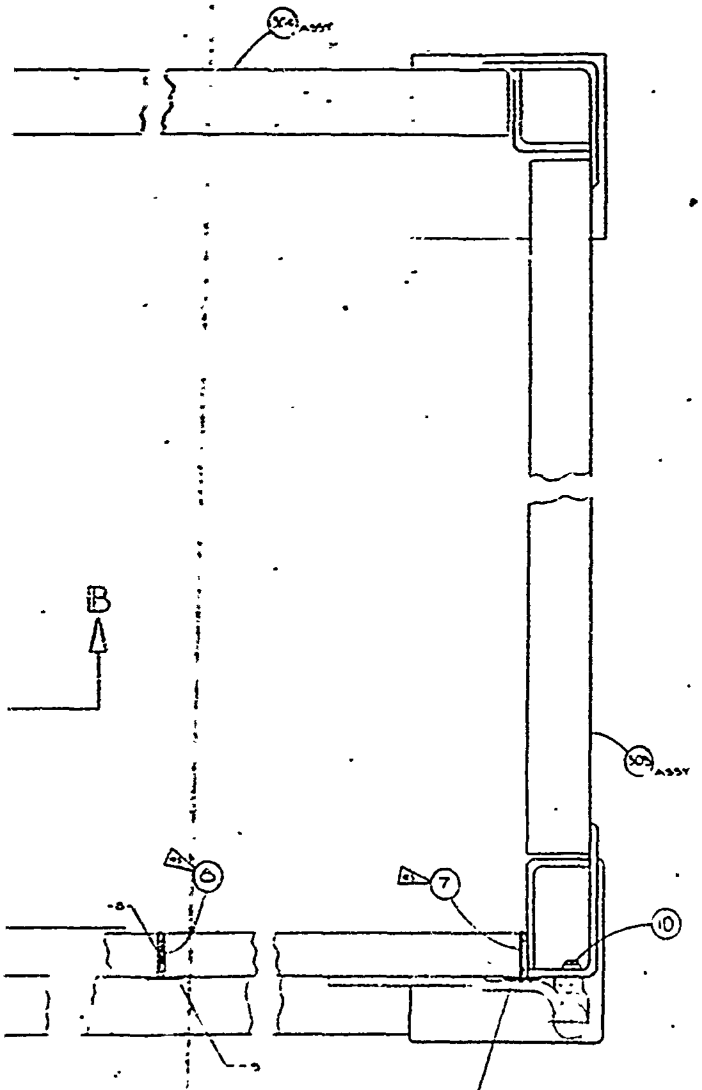




B - B
1/2 SIZE

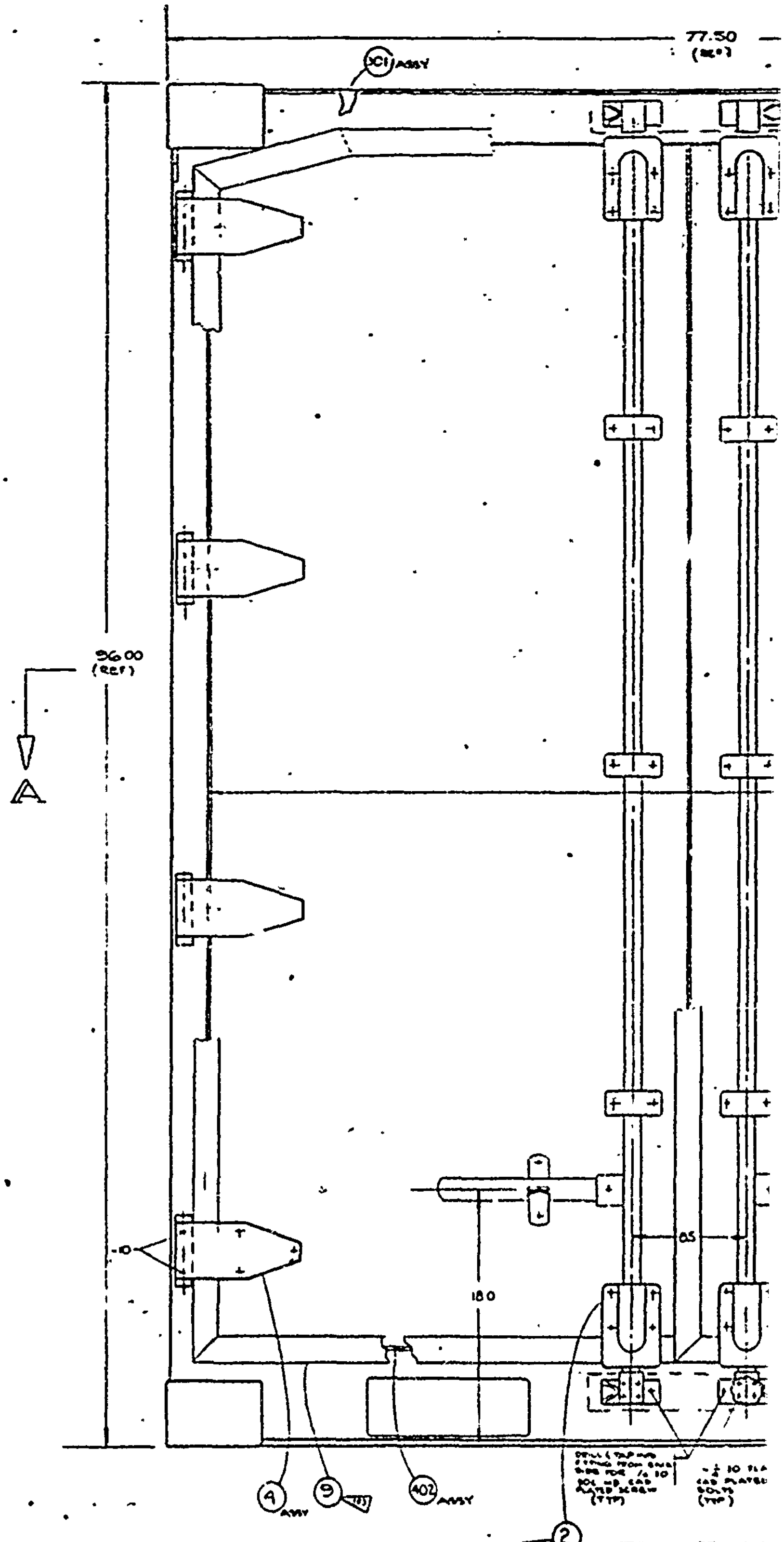
7

6



A - A

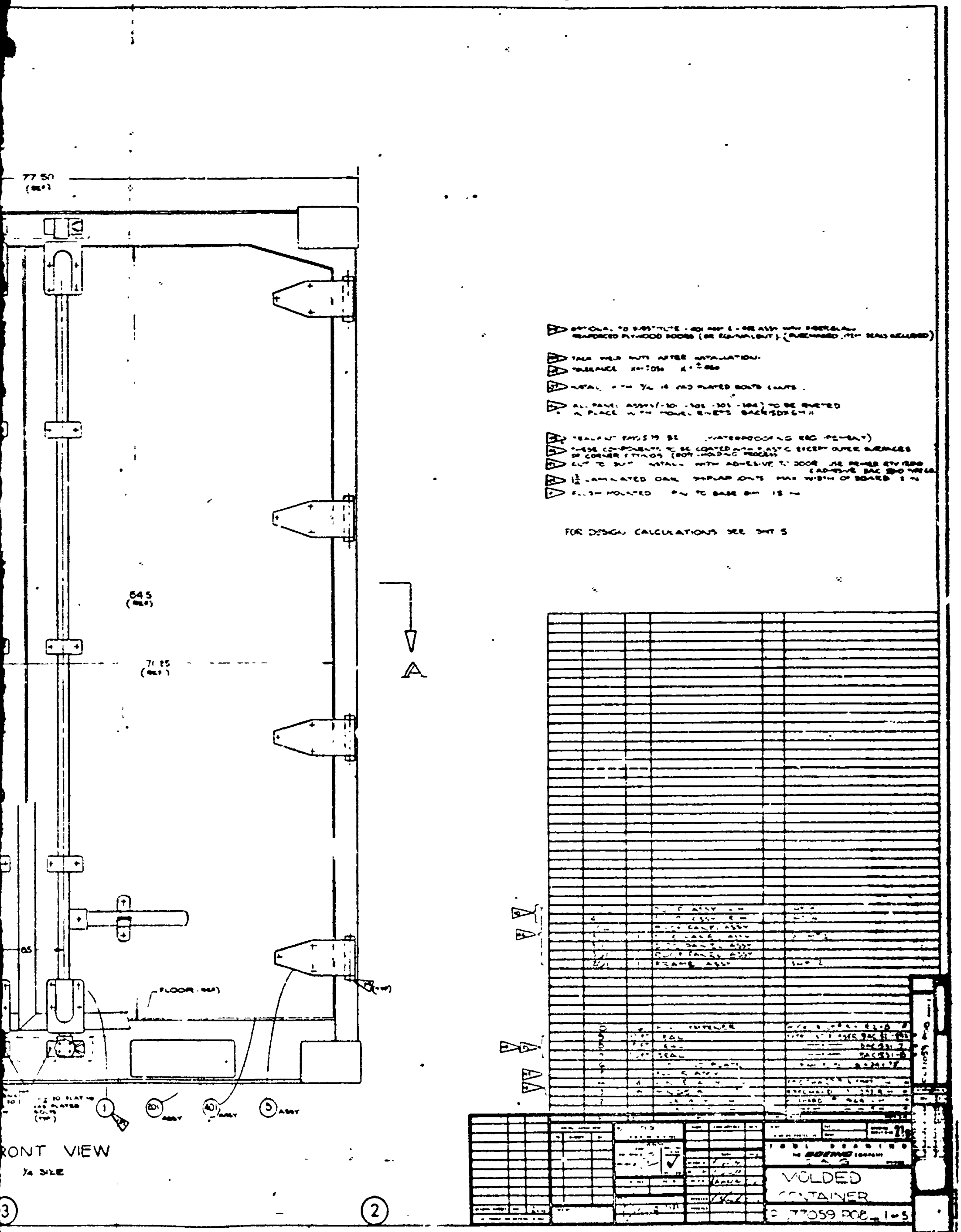
½ SIZE

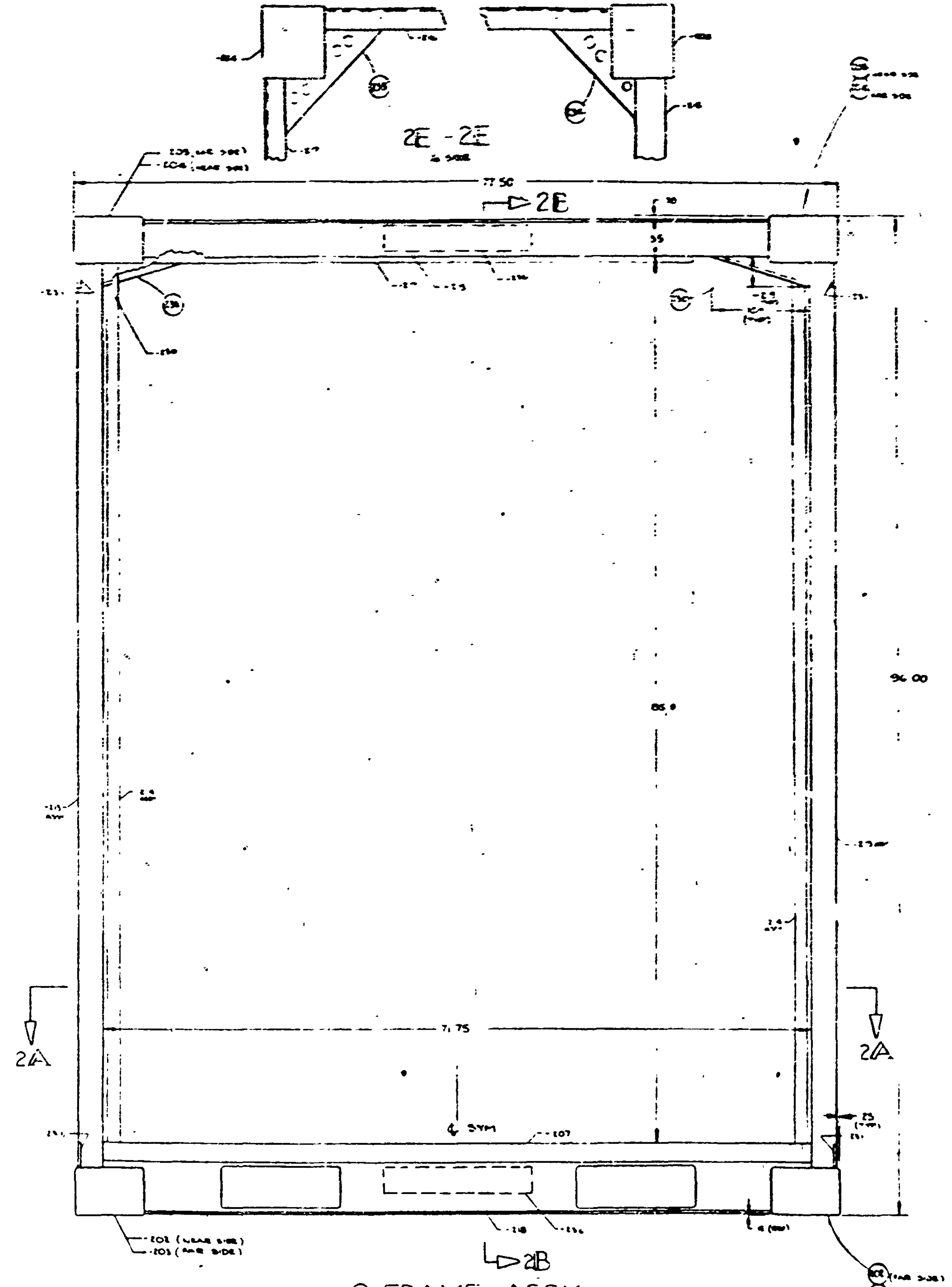


FRONT V

¼ SIZE

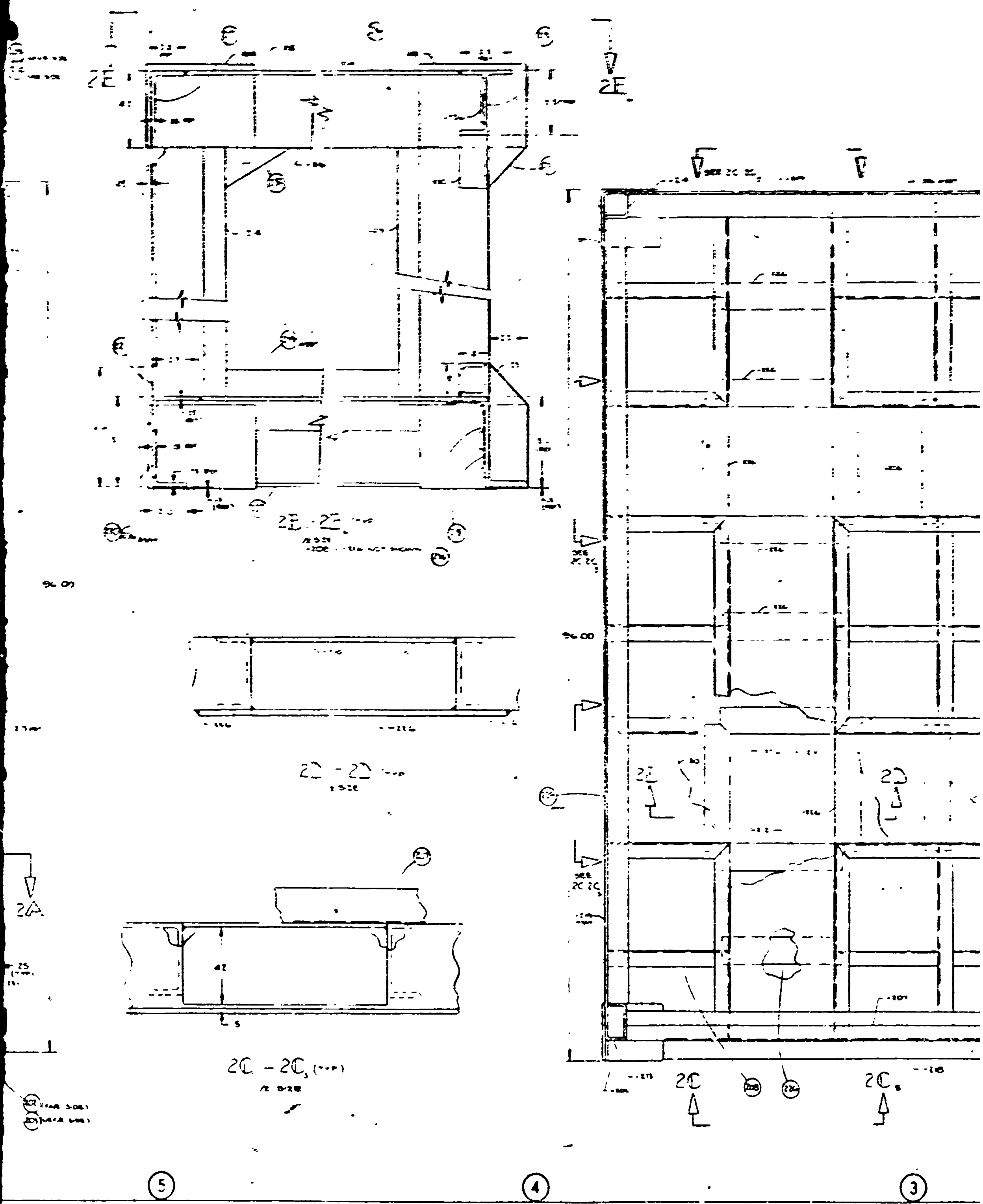
5 4 3

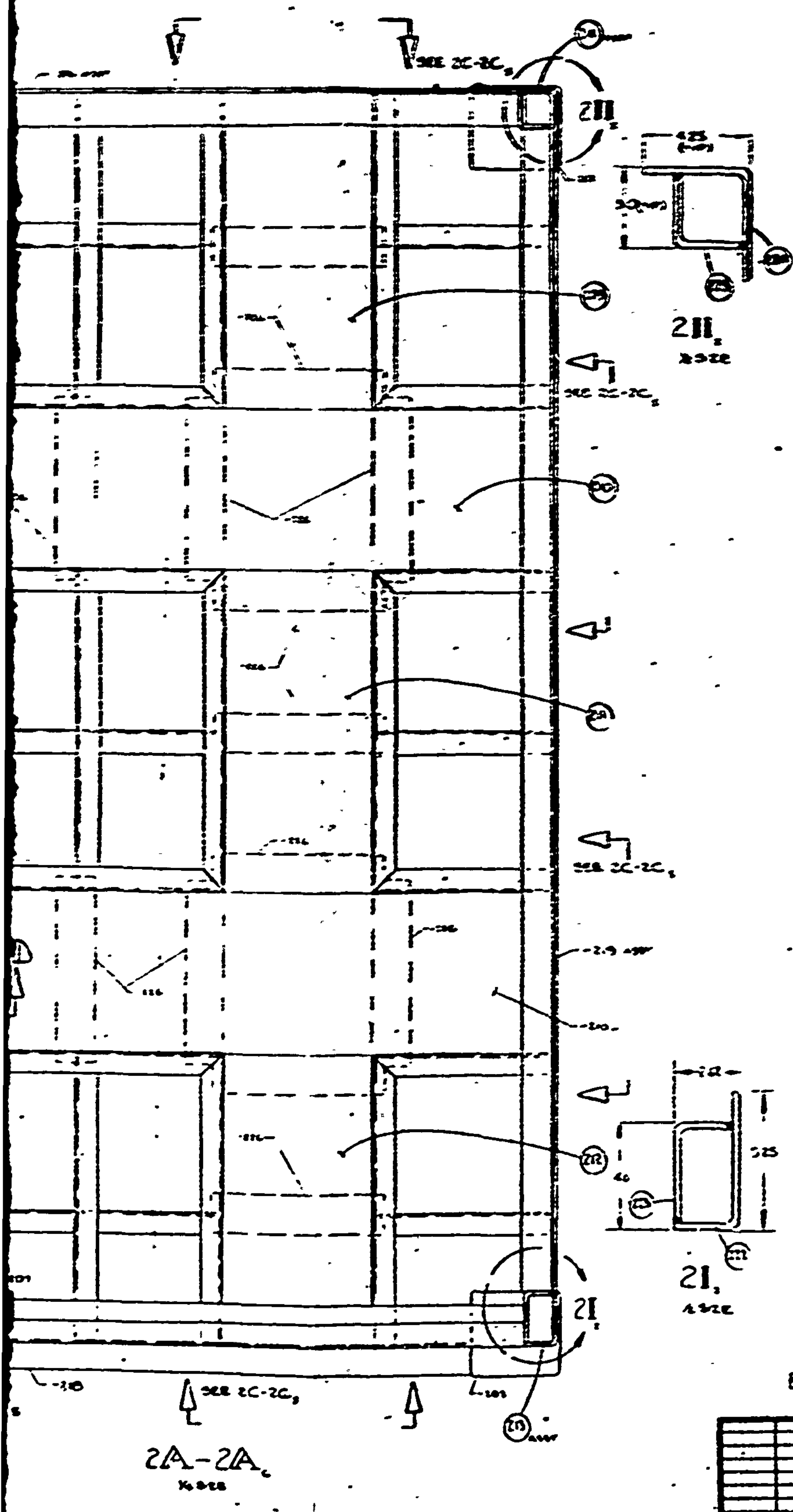

77.50 (REF)
64.5 (REF)
71.25 (REF)
FLOOR (REF)
FRONT VIEW
1/4 SIZE
FOR DESIGN CALCULATIONS SEE SHT 5
FRAME ASSY
BOEING
MOLDED
CONTAINER



201 FRAME ASSY

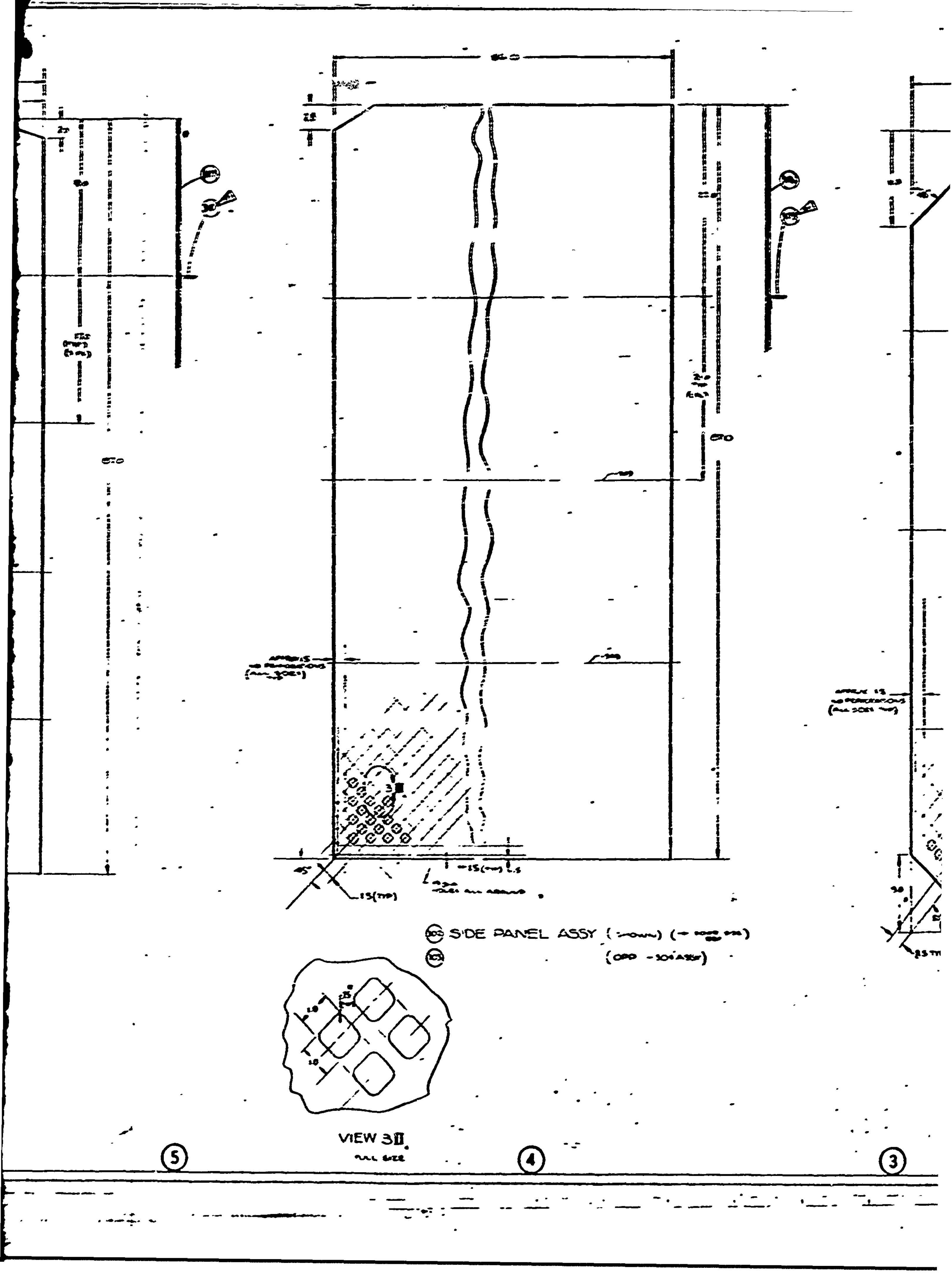
1/4 SIZE


2E
2E
2E - 2E (TYP)
96.00
2D - 2D (TYP)
42
2C - 2C (TYP)
2A
2C
2C
5
4
3

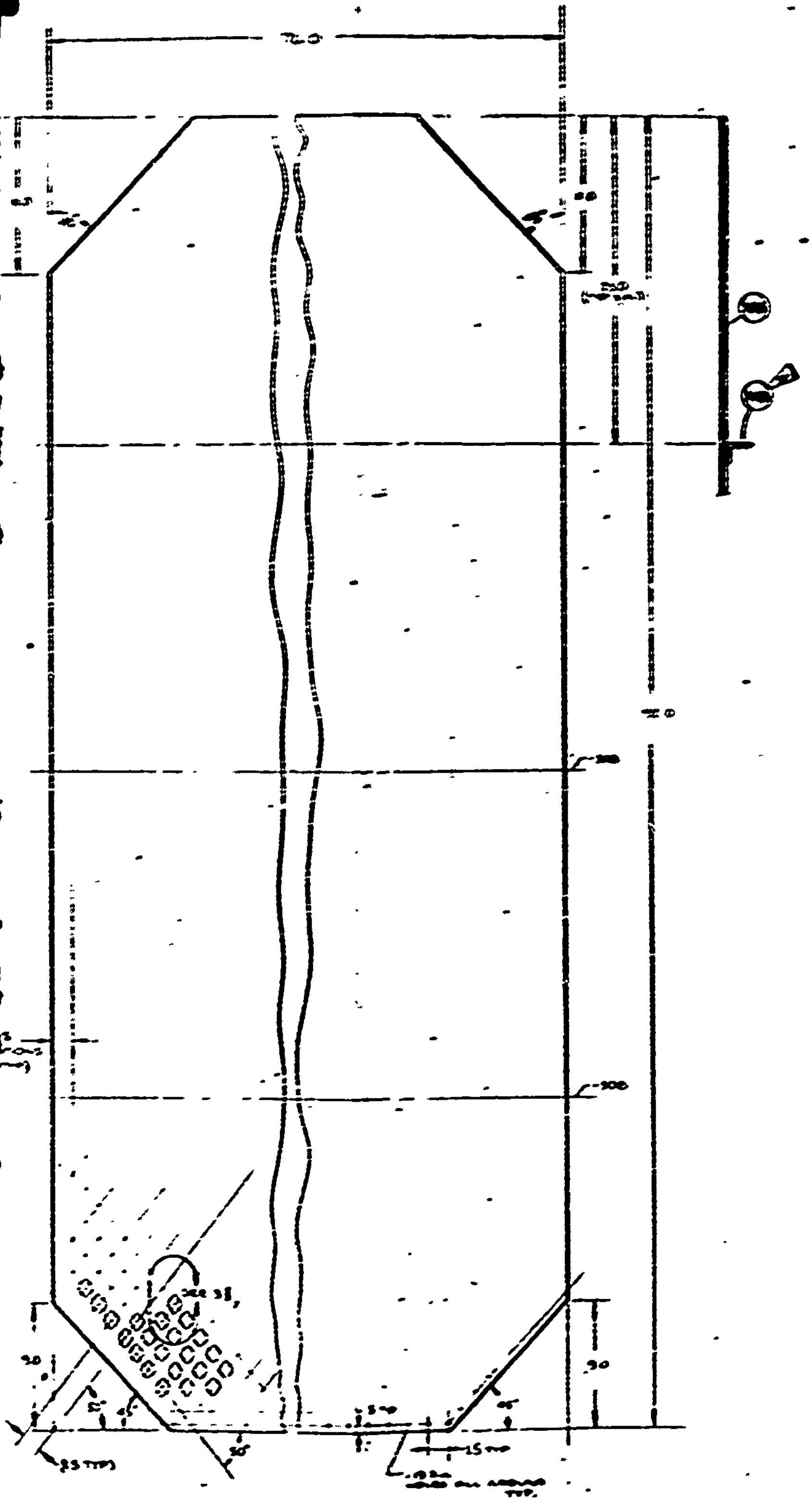


MOLDED CONTAINER

R677C59 ROL 2



SIDE PANEL ASSY
VIEW 3
5
4
3

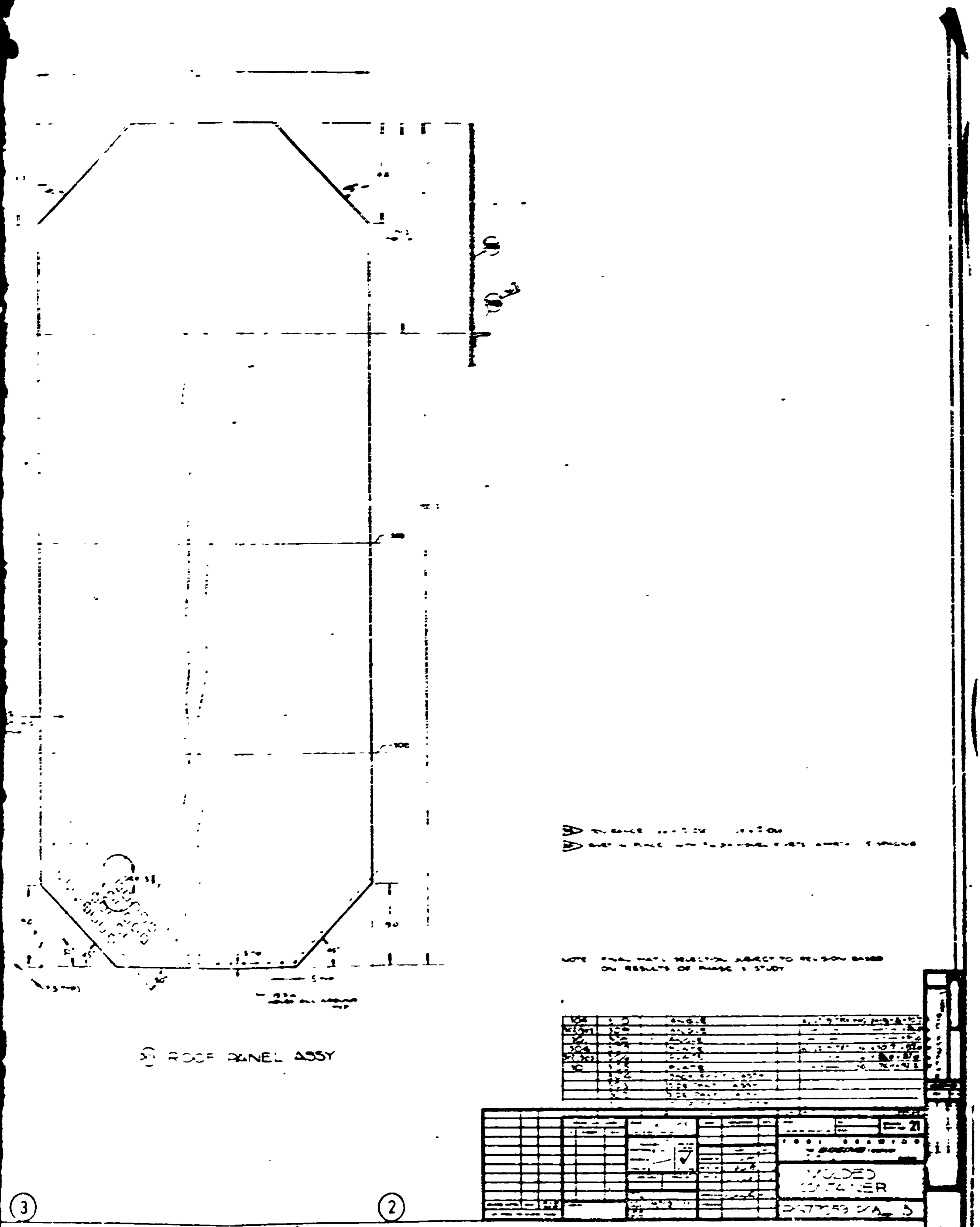


NOTE FINAL MAT'L SELECTION SUBJECT TO REVISION BASED ON RESULTS OF PHASE [illegible] STUDY

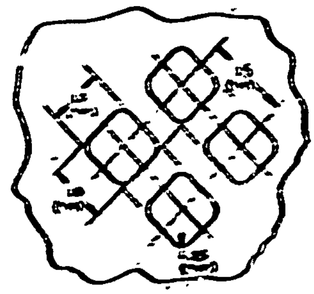
[illegible]	310	1	ANGLE		[illegible]
[illegible]	309	[illegible]	ANGLE		[illegible]
[illegible]	[illegible]	1	ANGLE		[illegible]
[illegible]	307	1	PLATE		[illegible]
[illegible]	[illegible]	[illegible]	PLATE		[illegible]
[illegible]	305	1	PLATE		[illegible]
	[illegible]	1	[illegible] PANEL ASSY		
	[illegible]	1	[illegible] PANEL ASSY		
	[illegible]	1	[illegible] PANEL ASSY		
	[illegible]	1	[illegible] PANEL ASSY		

MOLDED CONTAINER

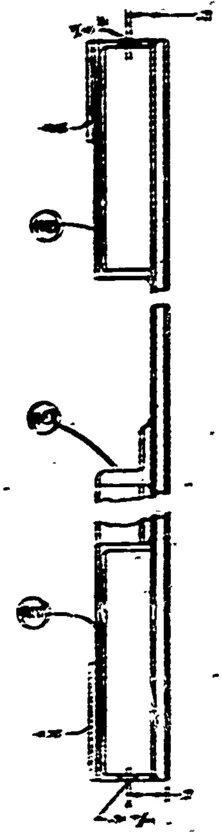
R677059 P03 3


ROOF PANEL ASSY
MOLDED CONTAINER

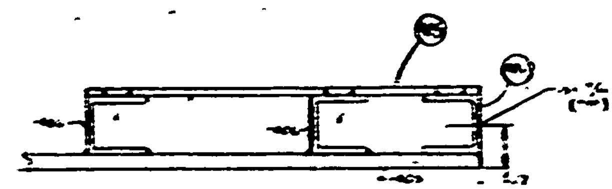
7 6



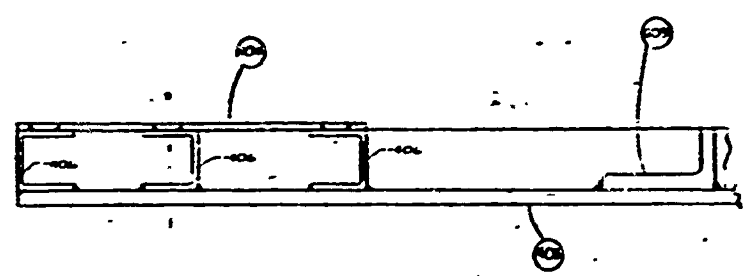
VIEW 4I,
FULL SIZE



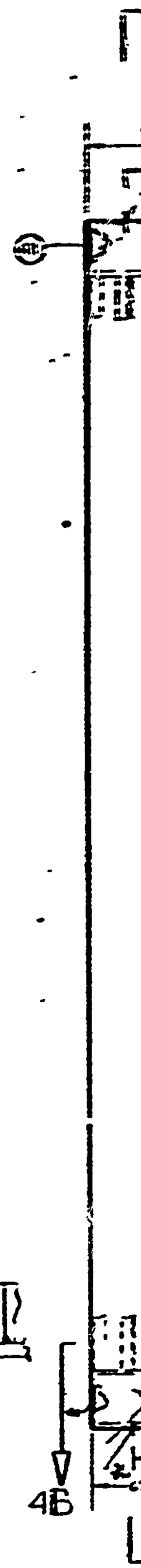
4C - 4C
FULL SIZE



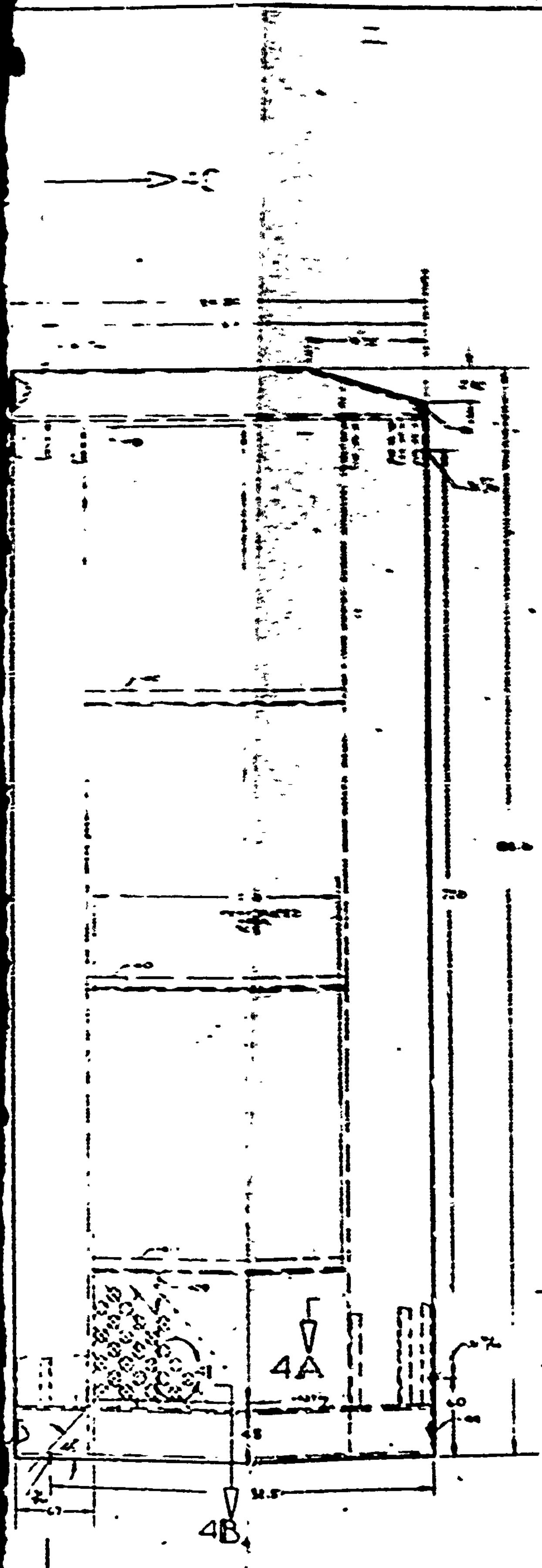
4A-4A,
FULL SIZE



4B -4B,
FULL SIZE



(5) (4) (3)



DOOR ASSY (R.H SHOWN)
(L.H OPP -401)

MOLDED CONTAINER

(2)

E-5

THE BOEING COMPANY

COMMERCIAL AIRPLANE DIVISION

RENTON, WASHINGTON

DOCUMENT NO. R677059 P08 SHT 5

TITLE: MOLDED CONTAINER
(DESIGN CALCULATIONS)

MODEL ______

ISSUE NO. ______ TO: ______ ______ (DATE)

REF. CONTRACT No. DAAK02-71-C-0201

PREPARED BY	P. Kutt	3-31-72
SUPERVISED BY	G. Fry	4-3-72
APPROVED BY	[illegible]	4/3/2
APPROVED BY		
		(DATE)

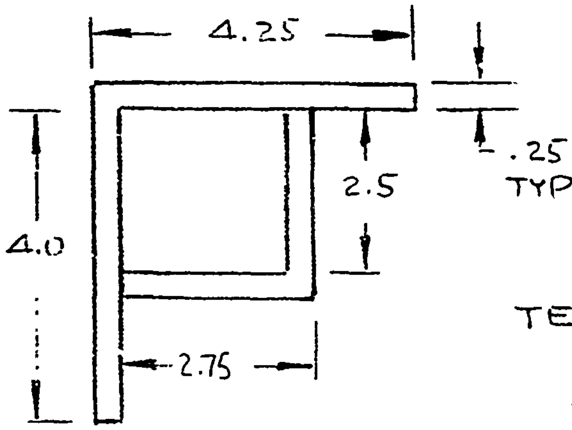
AD 1546 A

THIS FOLDER CONTAINS DESIGN CALCULATIONS PREPARED IN CONNECTION WITH THE DESIGN OF MOLDED CONTAINER.

SEE DWG. # R677059P08 SHT 1 THRU 5

TYPE LOAD	UNIT AND LOAD
Stacking S	Load test 77-1/2 inch unit to 26,879 pounds gross weight. Apply 100,800 pounds vertical load (S) to each top corner fitting in turn. Load S = 100,800 pounds
Lifting From Top T	Couple three 77-1/2 inch units together. Load to total gross weight of 89,600 pounds. Lift by the 4 top corner fittings using hooks in end holes or side holes. Load T = 22,400 pounds
Lifting From Bottom L	Couple three 77-1/2 inch units together. Load to total gross weight of 89,600 pounds. Attach sling to side holes in bottom corner fitting with line of action at 30° to the horizontal, and lift. Load L = 22,400/sine 30° = 44,800 pounds. Vertical component = 22,400 pounds, horizontal component = 39,000 pounds.
Horizontal Restraint B	Couple three 77-1/2 inch units together. Load to total gross weight of 44,800 pounds. Apply a compression load B, and then a tension load to each lower side rail in turn. Load B = (1.25) (gross weight) = 56,000 pounds.
Floor Load	(1) Load floor to a uniformly distributed load of 30,000 pounds (2) Load floor to a concentrated load of 6000 pounds over an area 3 x 7-1/3 inches.
Roof Load	Load roof to 660 pounds uniformly distributed over 12 x 24 inch area.
Wall Side Load W	(1) Apply a uniformly distributed load of 5460 pounds to either the R.H. or L.H. end wall. (2) Apply a uniformly distributed load of 8100 pounds to the door side and the blind side in turn.
Racking R	Restrain container through bottom corner fittings. Apply a compression and a tension load laterally and longitudinally, in turn, of 35,000 pounds to each top corner fitting in turn.

COMPRESSION TEST OF CORNER POSTS.

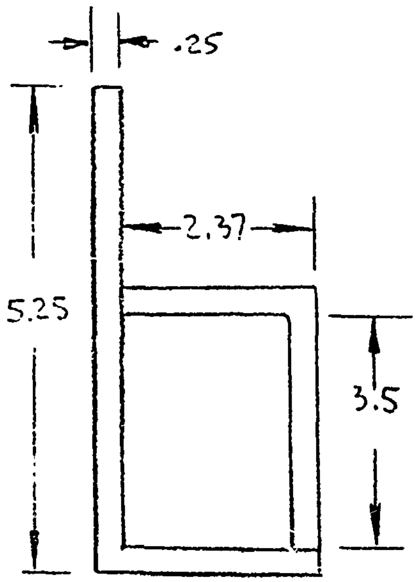


4.25 × .25 = 1.06
4.0 × .25 = 1.00
2.75 × .25 = .68
2.50 × .25 = .62

3.36 IN^2

TEST LOAD :

$$\frac{100'800}{3.36} \approx 32'000 \text{ PSI}$$ *



5.25 × .25 = 1.31
2 × 2.37 × .25 = 1.18
3.50 × .25 = .87

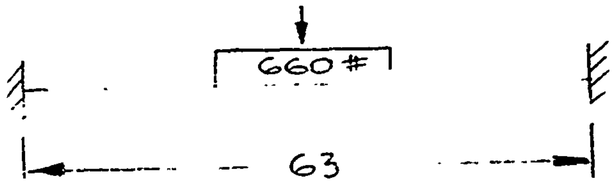
3.36 IN^2

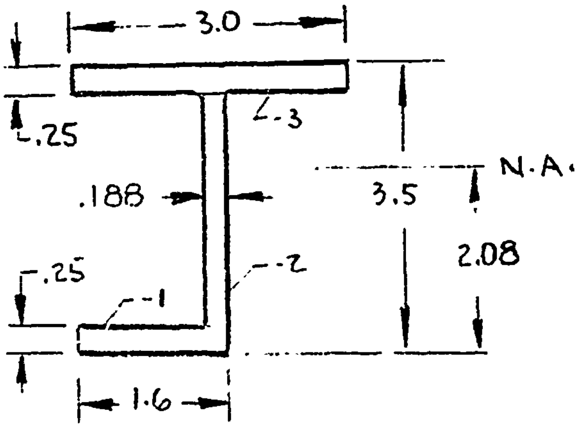
TEST LOAD :

$$\frac{10'800}{3.36} \approx 32'000 \text{ PSI}$$ *

* YIELD POINT
OF MAT'L 44'000 PSI

TEST LOADS OF ROOF BEAM (FRONT)





ITEM	A	$\bar{y}$	$A\bar{y}$	y	Ay^2	I_o	$I_o + Ay^2$
1	.400	.125	.050	1.955	1.52	.0020	1.522
2	.564	1.75	.986	1.330	1.0	.845	1.845
3	.750	3.375	2.53	1.295	1.24	.0039	1.244
	1.714		3.566				$I_{TOT} = 4.611 \text{ IN}^4$

$$\frac{3.566}{1.714} = 2.08$$

BENDING STRESS $S_1 = \dfrac{660 \times 63 \times 2.08}{4.611 \times 8} = 2350$ PSI

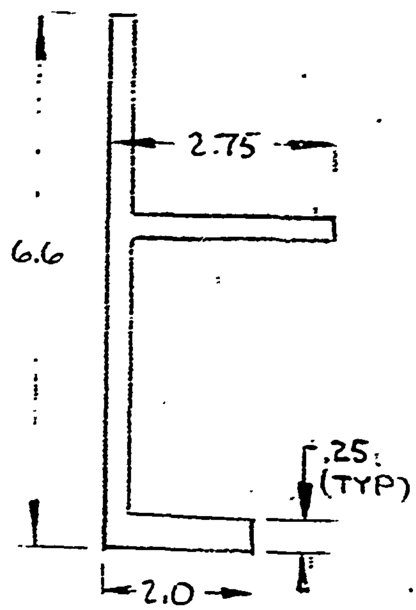
COMPRESSION STRESS $S_2 = \dfrac{35'000}{1.714} = 20'400$ PSI

YIELD POINT
OF MAT'L -40'000 PSI

DEFLECTION:

$$f = \frac{W l^3}{192 \ EI} = \frac{660 \times 250'047}{192 \times 10'300000 \times 4.611} = .018 \text{ IN.}$$

FLOOR SIDE BEAM COMPRESSION TEST.



$2.5 \times .25 = .625$
$1.75 \times .25 = .440$
$6.6 \times .25 = 1.650$
2.715 IN^2

FORK LIFT POCKET
$4.2 \times .25 = 1.05 \text{ IN}^2$

TOTAL AREA

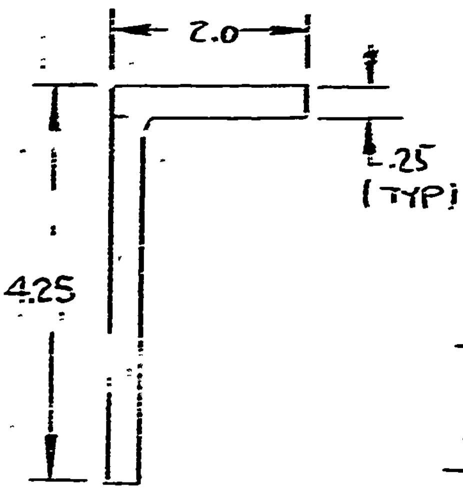
2.715
1.050
1.665 IN^2

COMPRESSION TEST: 56000 LBS

$$\frac{56000}{1.66} \approx 33800 \text{ PSI}$$

YIELD POINT
OF MAT'L – 44000 PSI

ROOF BEAM COMPESSION TEST.
(SIDES & BACK)

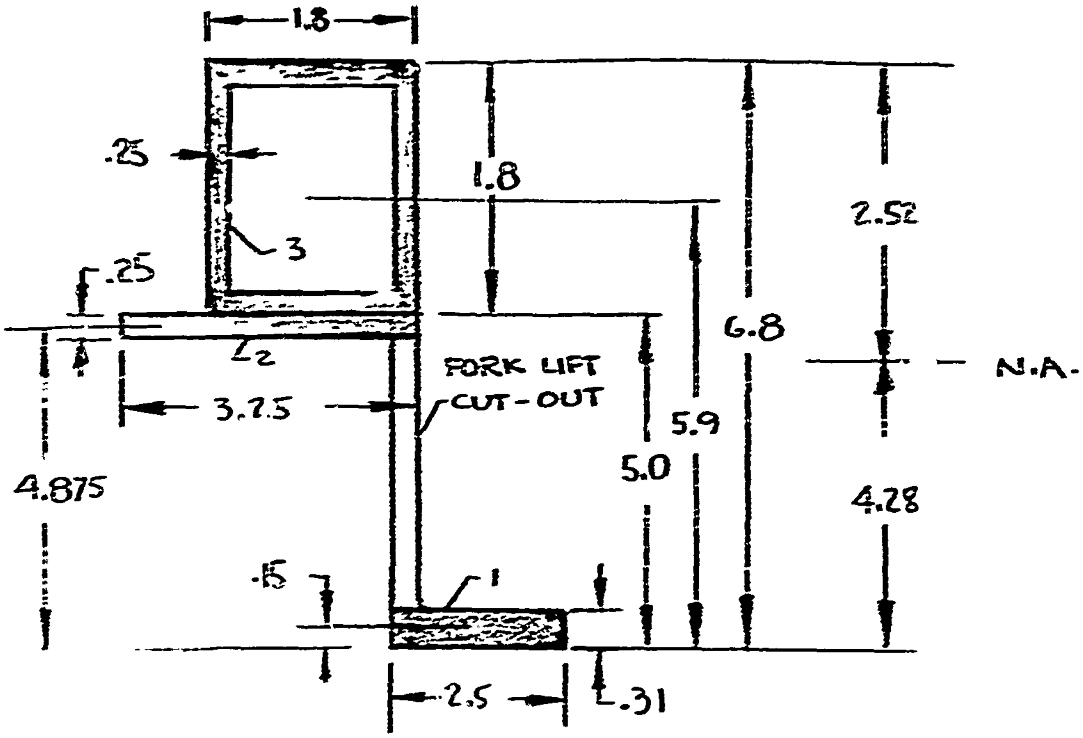


$4 \times .25 = 1.0$
$2 \times .25 = .5$
$.5 \text{ IN}^2$

TEST LOAD 35000 #

$\frac{35000}{1.5} \approx 23300$ PSI

FRONT FLOOR RAIL TEST LOADS.



ITEM 1 A = .77 I = .0062
ITEM 2 A = .66 I = .0034
ITEM 3 A = 1.55 I = .40

ITEM	A	$\bar{y}$	$A\bar{y}$	y	Ay^2	I_o	$I_o + Ay^2$
1	.77	.150	.116	3.97	12.12	.0062	12.1262
2	.66	4.875	3.580	.59	.233	.0034	.2364
3	1.55	5.900	9.150	1.62	4.07	.400	4.470
	2.98		12.846				$I_{TOT} = 16.83$

$\frac{12.846}{2.98} = 4.28$

TEST LOAD 30'000#
TOTAL LENGTH OF SIDES 347 IN.

$\frac{30\,000}{347} = 86.4$ LBS PER IN.

FRONT BEAM - 63" 63×86.4=5440#

COMPR. STRESS $\frac{56'000}{2.98} = 18'800$ PSI

BENDING STRESS $\frac{W \times L}{12\ Z} = \frac{5440 \times 63 \times 4.28}{12 \times 16.83} = 7300$ PSI.

DEFLECTION :

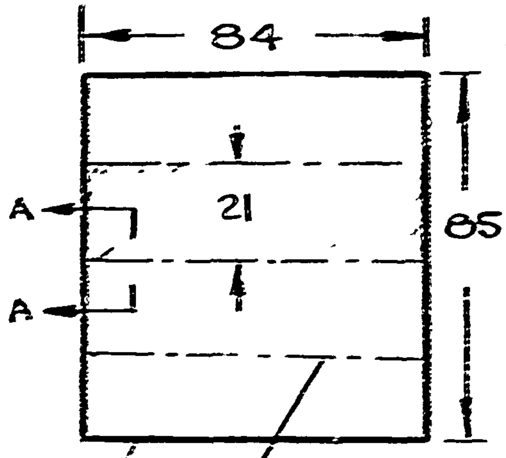
$$f = \frac{W l^3}{384\ EI} = \frac{5440 \times 63^3}{384 \times 10'300'000 \times 16.83} \approx .02 \text{ IN}$$

TEST LOAD OF SIDE PANELS -

SIDE WALL $88 \times 90 = 7920$ IN^2

TEST LOAD 5460 #

$\frac{5460}{7920} = .69$ PSI

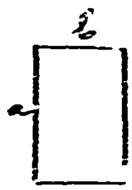


$\angle 2 \times 1\frac{1}{4} \times 1/4$ ANG.

$\angle$ .25 PLATE
66% OF CROSS SECTION REMOVED BY PERFORATION. EQUIVALENT PLATE WITHOUT PERFORATIONS $t = .083$

STRESS IN PLATE

$$S = \frac{.75 \times W \times b^2}{t^2(1 + 1.61\,\alpha^3)}$$



$\alpha = \frac{b}{a}$

t = THICKNESS

W = LOAD IN PSI

$W = .69$

$t = .083 \quad t^2 = .00689$

$\alpha = \frac{21}{84} = .25 \quad \alpha^3 = .01562$

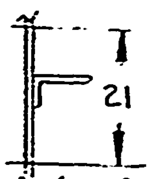
$b = 21 \quad b^2 = 441$

$$S = \frac{.75 \times .69 \times 441}{.00689(1 + 1.61 \times .015)} \approx 32000 \text{ PSI}$$ *

ASSUME A 21×84 BEAM LOADED .69 PSI

$21 \times 84 \times .69 = 1220$ LBS

STRESS IN ANGLE :



A - A

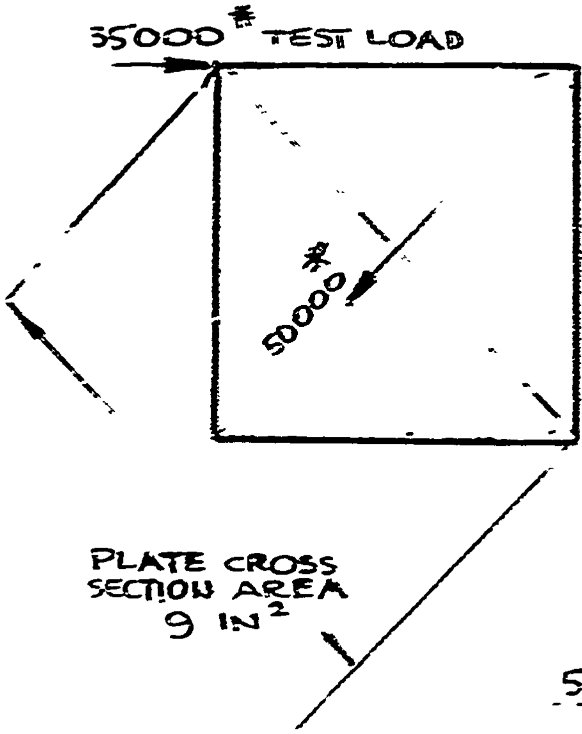
$2 \times 1\frac{1}{4} \times .25$ ANG.

$S = .224$

$$S = \frac{1220 \times 84}{12 \times .224} \approx 38000 \text{ PSI}$$ *

* YIELD POINT OF MAT'L 44000 PSI

RACKING TEST OF SIDE PANELS



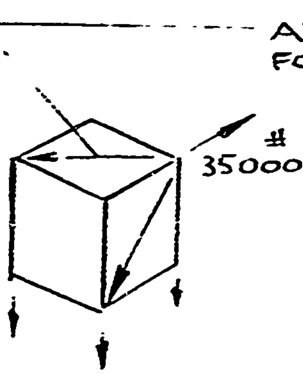
$$\frac{50\,000}{9} \approx 5500 \text{ PSI}$$

3/16 DIA MONEL RIVETS (BREAKING STRENGTH - SHEAR 1650# EACH)

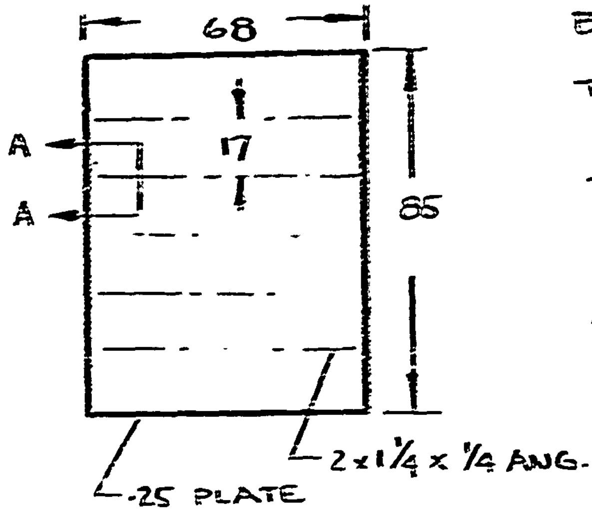
$$\frac{50\,000}{1650} \approx 30 \text{ RIVETS (MIN.)}$$

ACTUAL No. OF RIVETS -110 (APPROX.)

ADDITIONAL RESTRAINT TO RACKING FORCE IS PROVIDED BY DIAGONAL COMPONENTS OF ROOF PLATE.



TEST LOAD OF BACK PANEL (BLIND END)

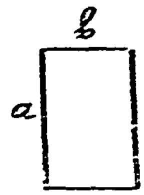


BACK WALL $85 \times 76 = 6688 \text{ in}^2$

TEST LOAD 8100 #

$$\frac{8100}{6688} = 1.21 \text{ PSI}$$

STRESS IN PLATE $S = \dfrac{.75 \times w \times b^2}{t^2(1 + 1.61\,\alpha^3)}$



$\alpha = \dfrac{b}{a}$

t = THICKNESS

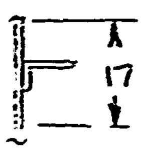
W = LOAD IN PSI

66% OF CROSS SECTION REMOVED BY PERFORATION.
EQUIVALENT PLATE WITHOUT PERFORATIONS $t = .083$

$w = 1.21$
$t = .083$
$\alpha = \dfrac{17}{68} = .25$
$b = 17$
$\alpha^3 = .01562$

$$S = \frac{.75 \times 1.21 \times 289}{.00689(1 + 1.61 \times .0156)} \approx 37{,}000 \text{ PSI}$$

*



A-A

ASSUME A 17 x 68 BEAM LOADED 1.21 PSI

$17 \times 68 \times 1.21 = 1400$ LBS.

STRESS IN ANGLE :

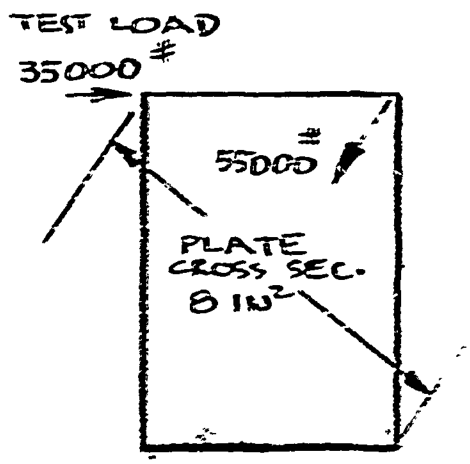
$$S = \frac{1400 \times 68}{12 \times .224} \approx 35{,}500 \text{ PSI}$$

*

2 x 1¼ x .25 ANG.
S = .224

* YIELD POINT OF MAT'L 44,000 PSI

RACKING TEST OF BACK PANEL.
(BLIND END)

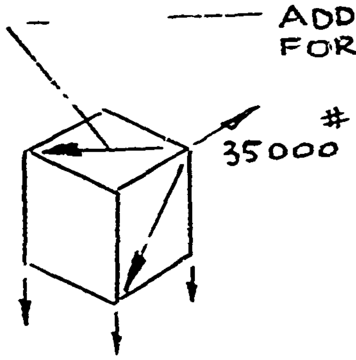


$$\frac{55000}{8} \approx 6900 \text{ PSI}$$

$\frac{3}{16}$ DIA MONEL RIVETS (SHEAR BREAKING STRENGTH: 1650# EACH)

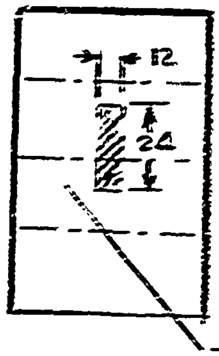
$$\frac{55000}{1650} = 34 \text{ RIVETS (MIN)}$$

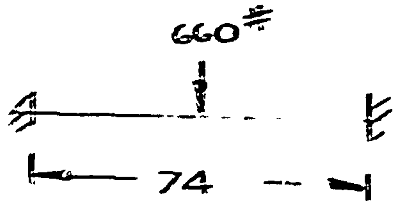
ACTUAL No. OF RIVETS ~ 100 (APPROX.)



ADDITIONAL RESTRAINT TO RACKING FORCE IS PROVIDED BY DIAGONAL COMPONENTS OF ROOF PLATE.

TEST LOAD OF ROOF PANEL.



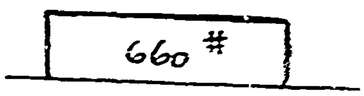


ASSUM THE TEST LOAD IS SUPPORTED BY ONE CROSS MEMBER.

(L ANG. 2 × 1¼ × ¼   S = .22)

$$\frac{660 \times 74}{8 \times .22} = 28{,}000 \text{ PSI}$$

IF HALF OF THE TEST LOAD IS SUPPORTED BY PERFORATED PLATE.



$12 \times 24 = 288 \text{ IN}^2$

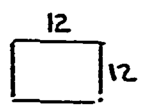
$$\frac{660}{2} = 330\#$$

$$\frac{288}{2} = 144 \text{ IN}^2$$

$$\frac{330}{144} = 2.3 \text{ PSI}$$

STRESS IN PLATE (AREA 12 × 12)

$$S = \frac{.75 \times W \times \ell^2}{t^2 (1 + 1.61\, \alpha^3)}$$



$a = \ell = 12$

$\alpha = \frac{\ell}{a} = 1$

W = LOAD PSI

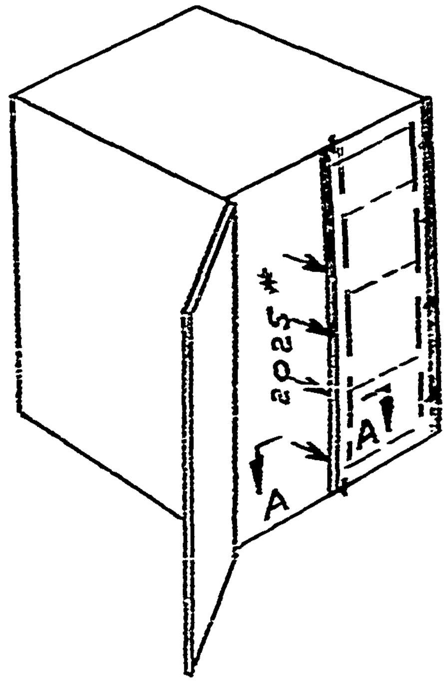
$t = .083$ $t^2 = .0068$

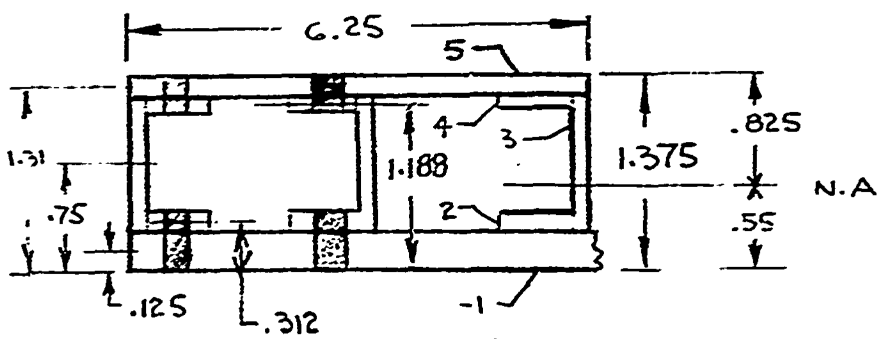
$$S = \frac{.75 \times 2.3 \times 144}{.0068 \times 2.61} = 14{,}000 \text{ PSI}$$

AS PERFORATIONS REMOVE 1/3-RD OF CROSS SECTION

$t = .083 \times 3 = .25$

TEST LOADS OF DOOR





A-A

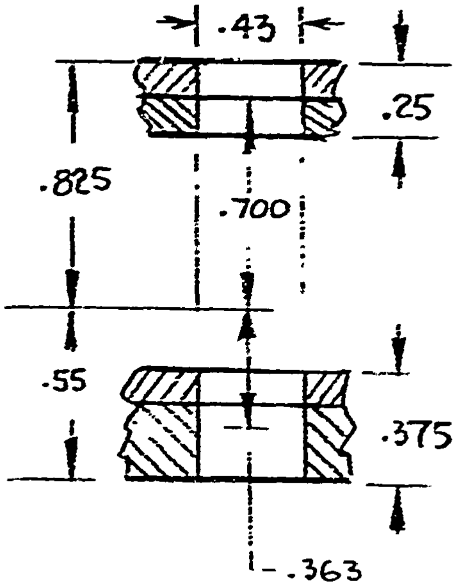
ITEM	A	$\bar{y}$	$A\bar{y}$	y	Ay^2	I	MULTIPLY	$I + Ay^2$
1	1.560	.125	.195	.425	.281	.00815	1	.289
2	.109	.312	.034	.238	.0061	.00014	3	.019
3	.125	.750	.094	.200	.005	.0104	3	.046
4	.109	1.188	.130	.638	.0444	.00014	3	.133
5	.780	1.312	1.020	.762	.452	.0010	1	.453
	2.683		1.473					

$I_{TOT} = .940 \text{ IN}^4$

$\frac{1.473}{2.683} = .55$

(CONTINUED)

REDUCTION IN I VALUE ON ACCOUNT OF HOLES IN VERT. DOOR FRAME



$I_1 = .00056$

$Ay^2 = .05260$

$.05316 \times 2 = .106$

$I_2 = .0019$

$Ay^2 = .0211$

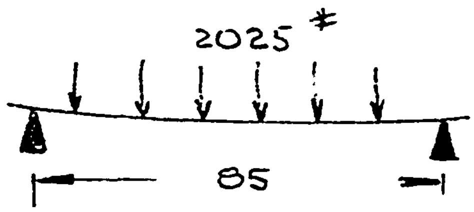
$.0230 \times 2 = .046$

$I = .152 \text{ IN}^4$

ADJUSTED I

$.940 - .152 = .788 \text{ IN}^4$

BENDING STRESS IN VERTICAL DOOR FRAME.



TEST LOAD $\frac{8100}{4} = 2025$ #

MAX STRESS $\frac{2025 \times 85 \times .825}{8 \times .788} = 22\,500$ PSI

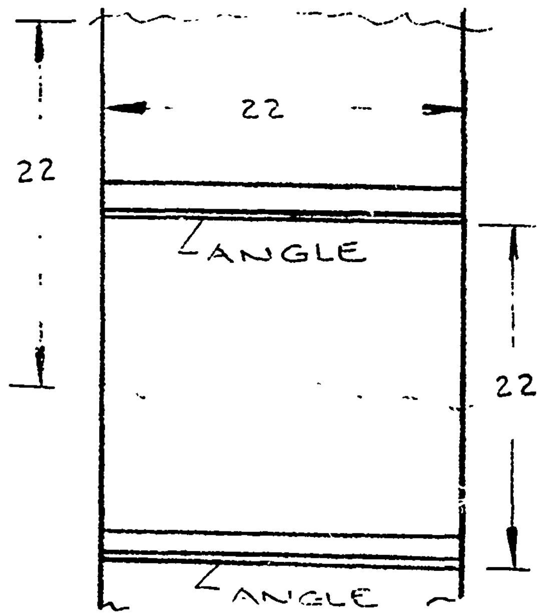
YIELD POINT OF MAT'L ≈ 44000 PSI

DEFLECTION:

$$f = \frac{5 W l^3}{384 \; E I}$$

$$f = \frac{5 \times 2025 \times 614125}{384 \times 10\,300\,000 \times .788} = 2.0 \text{ IN.}$$

TEST LOADS OF DOOR PANEL



TEST LOAD 8100 #

FRONT SURFACE
88 × 76 = 6688 IN^2

$$\frac{8100}{6688} = 1.21 \text{ PSI}$$

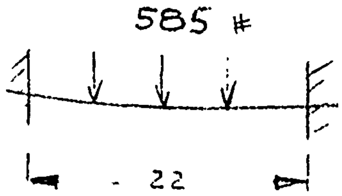
STRESS IN ANGLE

1 × 1 × 1/4 ANG.

22 × 22 × 1.21 = 585 LBS

I = .0361 IN^4

S = .0544 IN^3



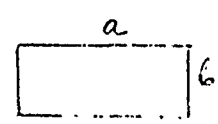
$$\frac{585 \times 22}{12 \times .0544} = 19{,}800 \text{ PSI}$$

YIELD POINT OF MAT'L = 44,000 PSI

STRESS IN PERFORATED PLATE

$$S = \frac{.75 \times W \times b^2}{t^2 (1 + 1.61 \alpha^3)}$$

$\frac{b}{a} = \alpha$



$$S = \frac{.75 \times 1.21 \times 484}{.00697 \times 2.61}$$

W = 1.36 PSI

(t_1 = .0835) t^2 = .00697

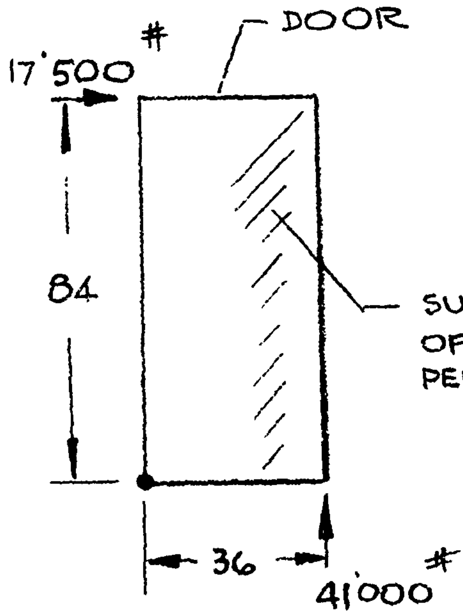
AS PERFORATIONS REMOVE 1/3 RD OF CROSS SECTION

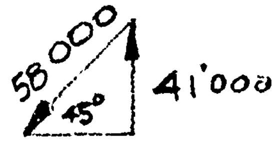
t = .0835 × 3 = .25

S = 24,000 PSI

a = b = 22

RACKING TEST OF CONTAINER FRONT
(WITH DOORS CLOSED)



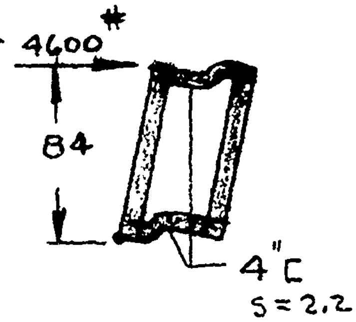


SUM OF CROSS SECTION AREAS OF DIAGONAL MEMBERS OF PERFORATED PLATE - 4.5 IN²

$$\frac{58'000}{4.5} \approx 13'000 \text{ PSI}$$

STRESS IN DOOR PLATE.

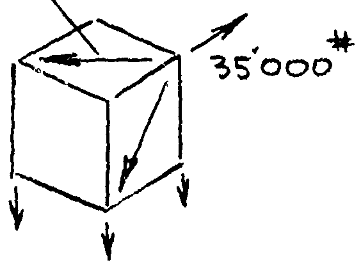
IN ADDITION 4600# OF FORCE CAN BE BALANCED BY HORIZ. DOOR FRAME, WHICH WOULD HAVE TO BEND AT (2) PL. EACH.



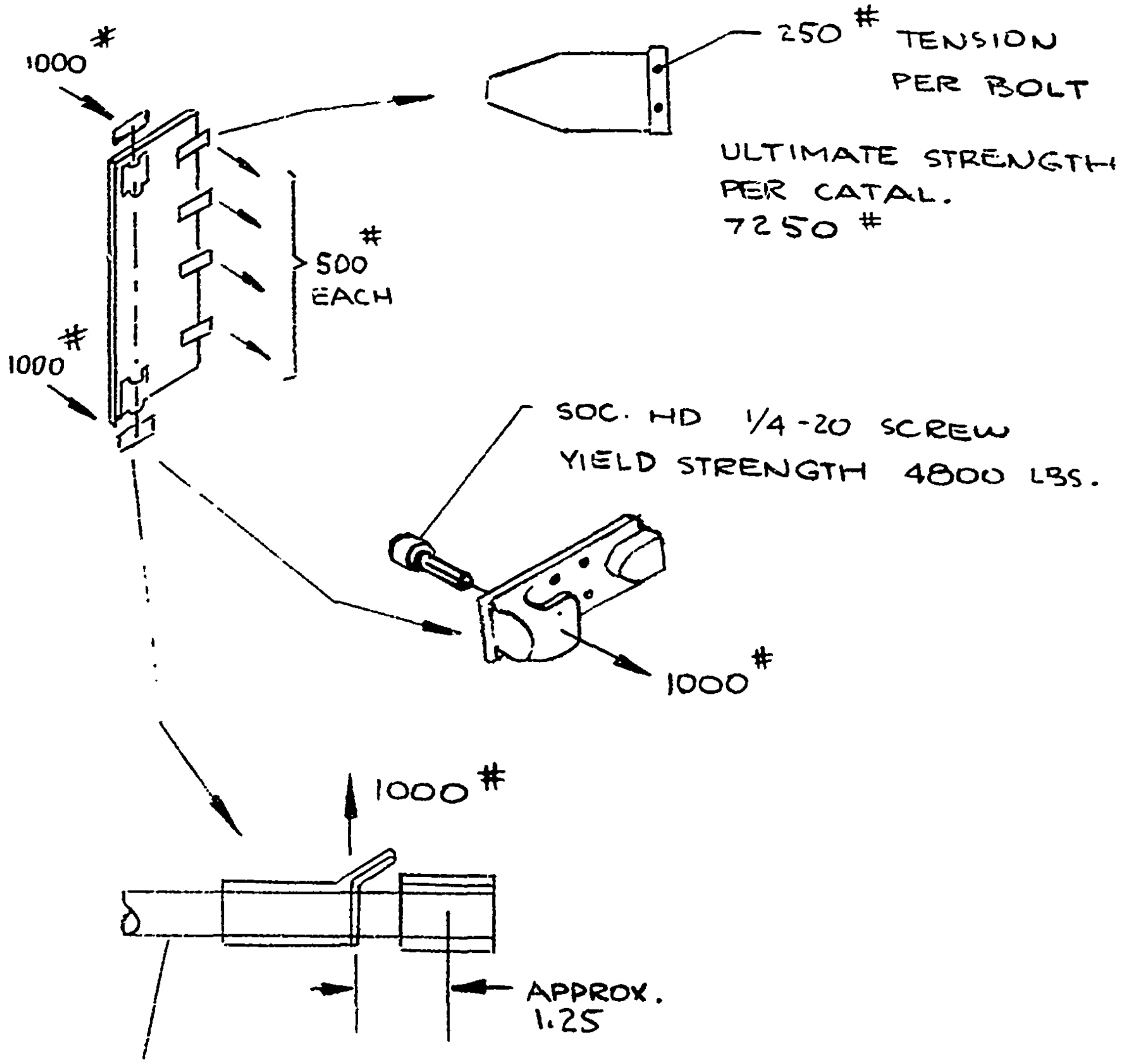
$$\frac{4600 \times 84}{4 \times 2.2} \approx 44'000 \text{ PSI}$$

YIELD POINT

ADDITIONAL RESTRAINT TO RACKING FORCE IS PROVIDED BY DIAGONAL COMPONENTS OF ROOF PANEL.



TEST LOAD STRESSES IN DOOR HARDWARE.



1.31 O.D. PIPE

$Z = .133 \text{ IN}^3$

$A = .49 \text{ IN}^2$

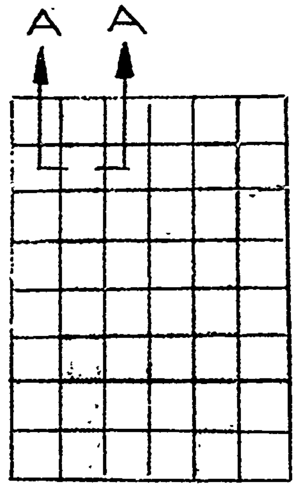
BENDING STRESS :

$$\frac{1000 \times 1.25}{.133} \approx 9400 \text{ PSI}$$

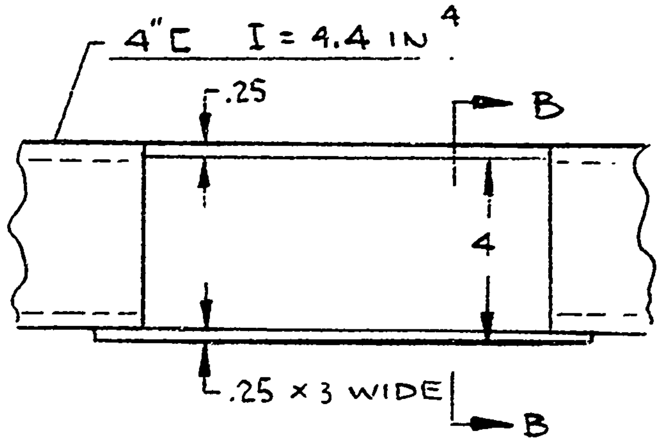
SHEAR STRESS

$$\frac{1000}{.49} \approx 2040 \text{ PSI}$$

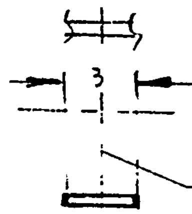
FLOOR LOAD TEST.



FLOOR FRAME



A – A



B - B

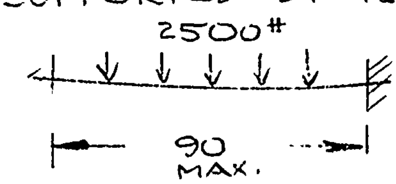
ASSUME A PAIR OF PLATES AS PART OF A BEAM.

$I = 6.0 \text{ IN}^4$

THUS FROM WALL TO WALL EACH CROSS MEMBER HAS $I = 4.4 \text{ IN}^4$ MIN.

(1) UNIFORM TEST LOAD 30000#

SUPPORTED BY 12 CROSS MEMBERS.

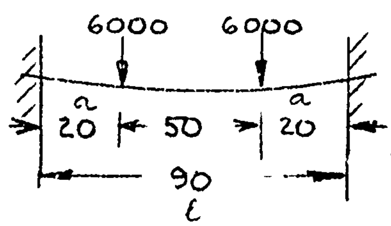


$\frac{30000}{12} = 2500$ * ASSUMED LOAD ON EACH BEAM.

* BENDING STRESS $\frac{WL}{12\,Z} = \frac{2500 \times 90 \times 2}{12 \times 4.4} \approx 8500$ PSI.

* DEFLECTION : $f = \frac{W\ell^3}{384\,EI} = \frac{2500 \times 729000}{384 \times 10300000 \times 4.4} = .105$ IN.

(2) WHEEL LOAD TEST.

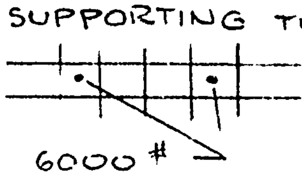


* BENDING STRESS $\frac{Wa}{Z} = \frac{6000 \times 20 \times 2}{4.4 \times 7} = 7800$ PSI.

* DEFLECTION : $I_1 = 7 \times 4.4 = 30.8 \text{ IN}^4$

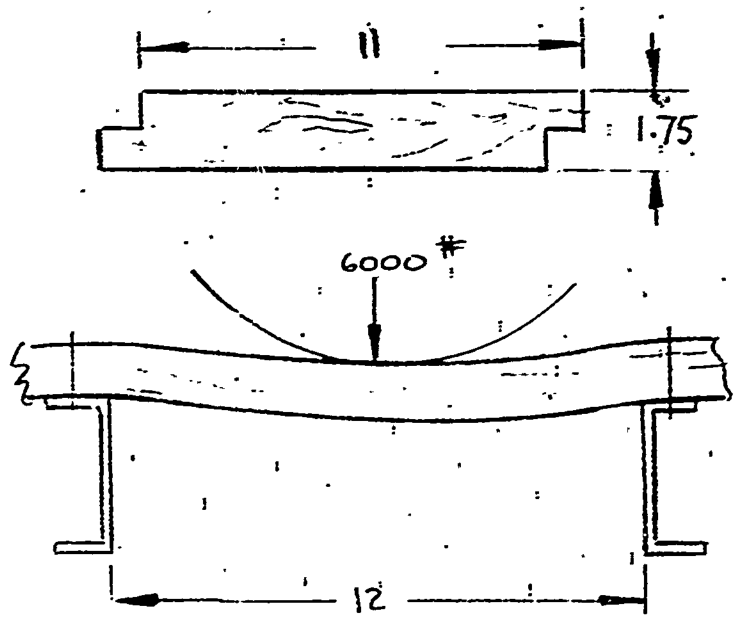
$$f = \frac{Wa(3\ell^2 - 4a^2)}{24\,EI} = \frac{6000 \times 20 \times 22700}{24 \times 10300000 \times 30.8} \approx .358$$

ASSUME (7) BEAMS SUPPORTING THE (2) LOADS.



* NOTE: RESISTANCE OF OAK FLOOR NEGLECTED.

OAK FLOOR LOAD TEST.



$Z = 5.6 \text{ IN}^3$

BENDING STRESS $S = \frac{6000 \times 12}{8 \times 5.6} \approx 1610$ PSI

* ALLOWED 1866 PSI.

SHEAR STRESS (SHEARING 3 x 7.3" FOOTPRINT")

TOTAL SHEAR AREA

$2 \times 3 = 6$

$2 \times 7.3 = 14.6$

$20.6 \times 1.75 = 36 \text{ IN}^2$

$\frac{6000}{36} = 167$ PSI

* ALLOWED 167 PSI

COMPR STRESS

"FOOTPRINT" $3 \times 7.3 = 21.9 \text{ IN}^2$

$\frac{6000}{21.9} \approx 275$ PSI

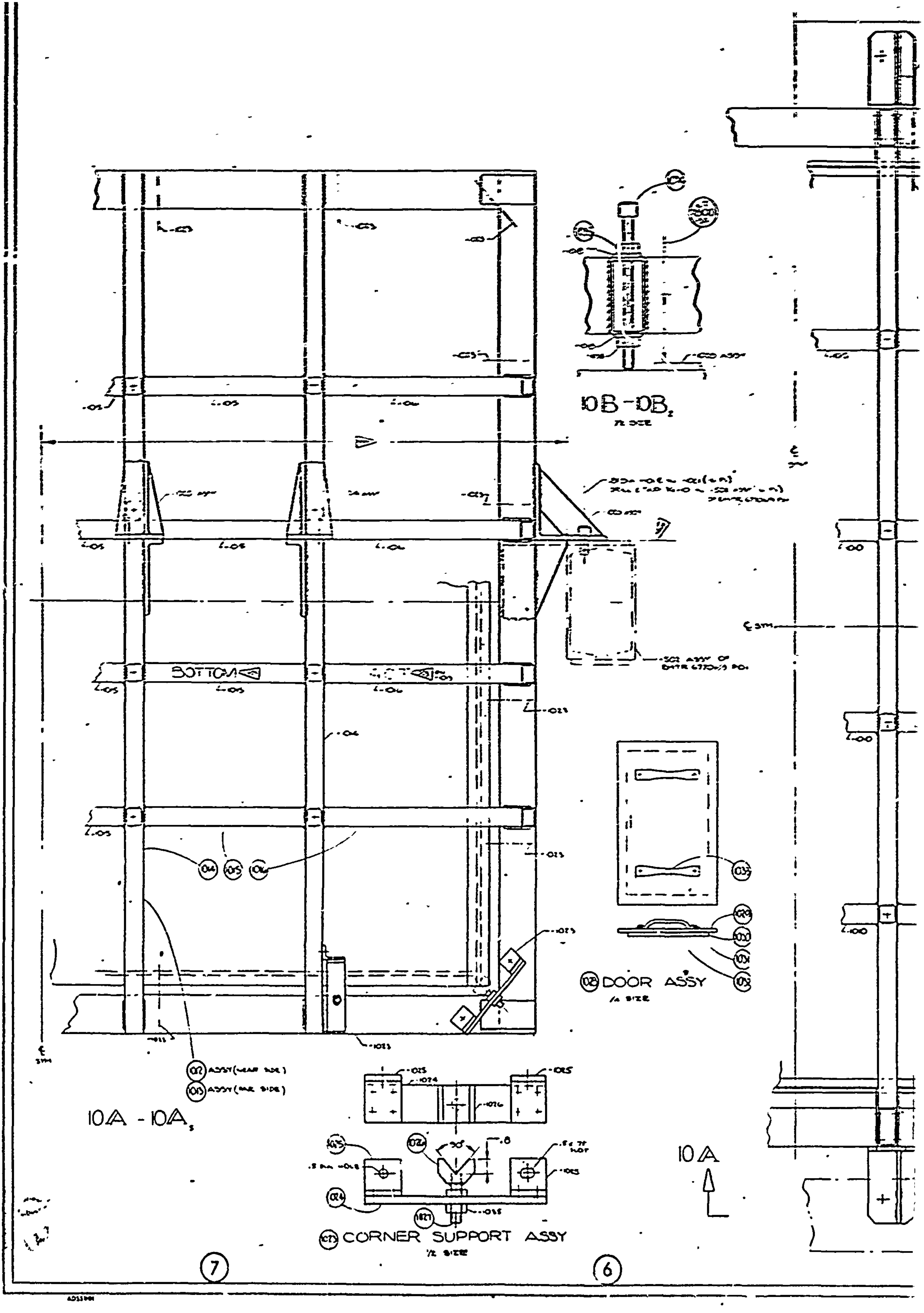
* ALLOWED 500 PSI

---

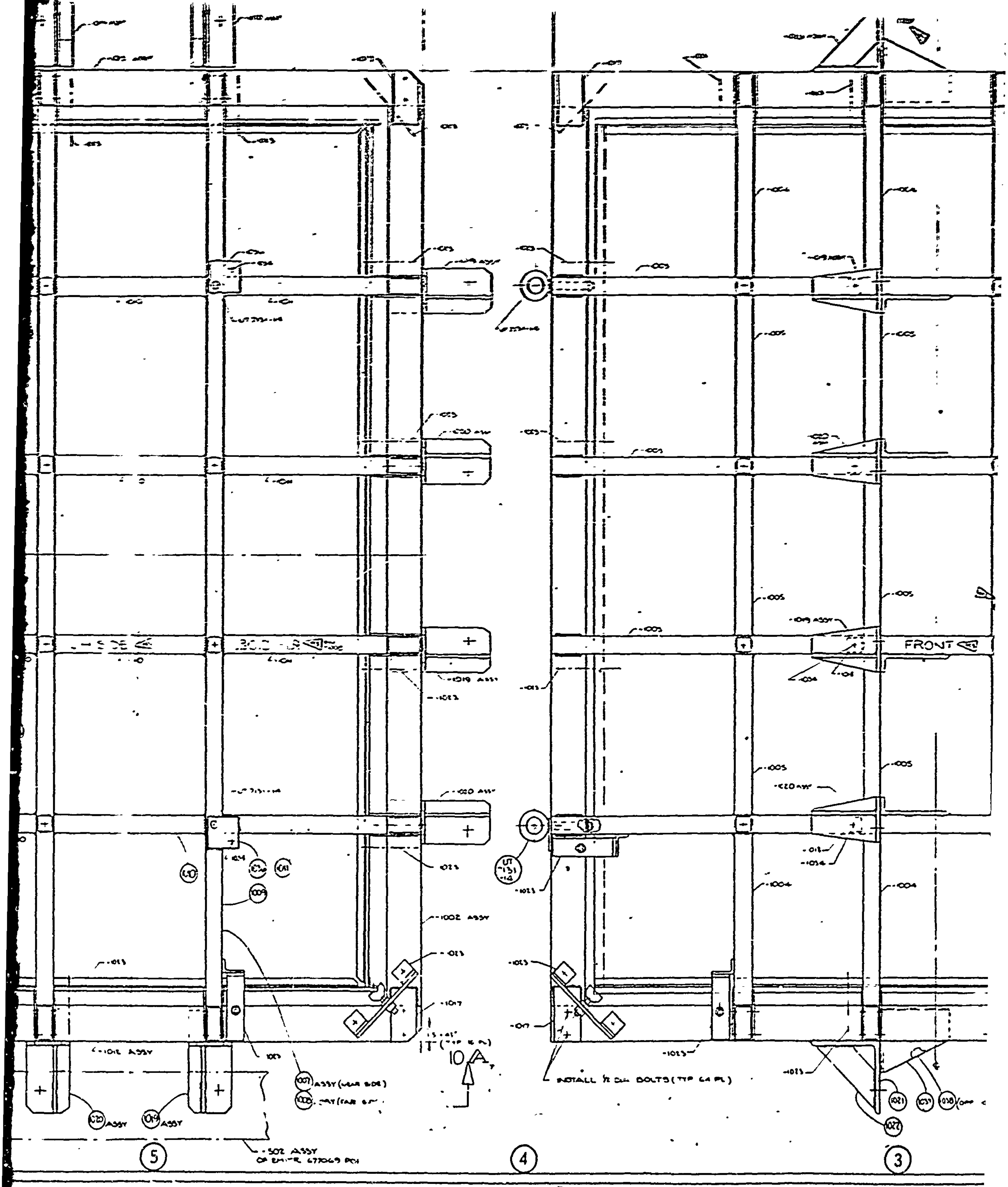
* PER MARK'S HANDBOOK
PAGE 7-4 TABLE 4.

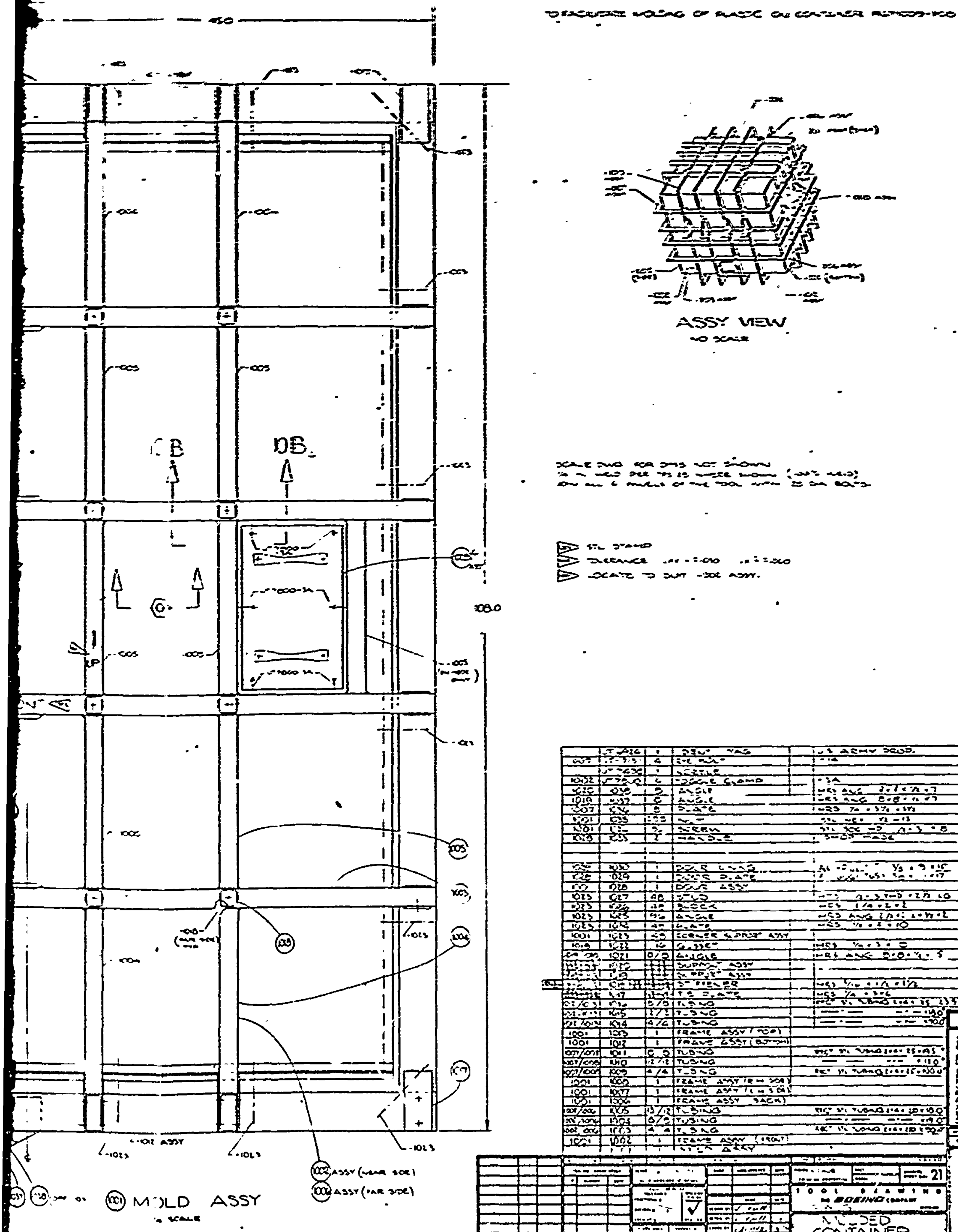
APPENDIX F

ENGINEERING DRAWINGS OF FULL SIZE
TRICON ROTATION MOLD



10B - 10B2
BOTTOM
DOOR ASSY
ASSY (NEAR SIDE)
ASSY (FAR SIDE)
10A - 10A5
CORNER SUPPORT ASSY
1/2 SIZE
10A
7
6

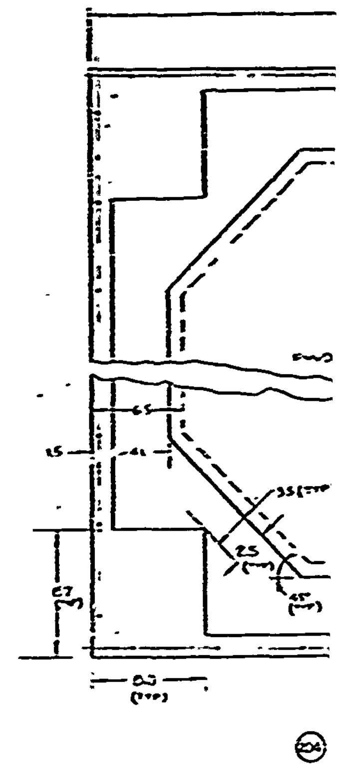

FRONT
INSTALL ½ DIA BOLTS (TYP 64 PL)
-1002 ASSY
-1019 ASSY
-1020 ASSY
-502 ASSY
10A
5
4
3

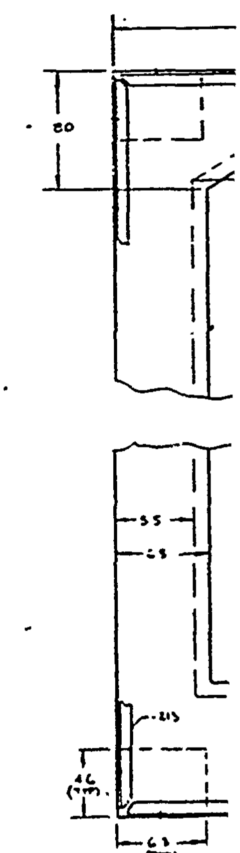


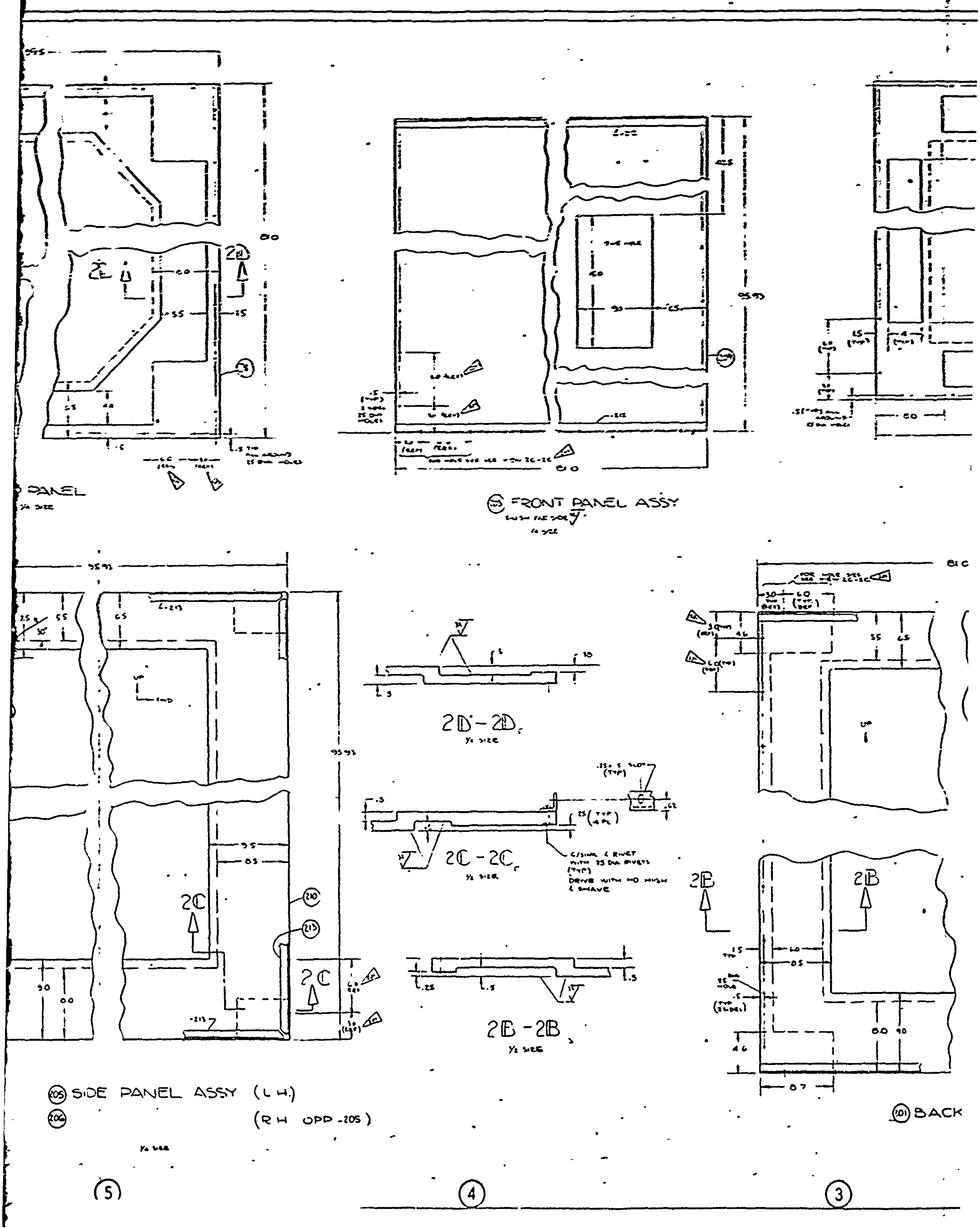
[illegible]	[illegible]	1	[illegible]	U.S. ARMY PROP.
[illegible]	[illegible]	4	[illegible]	[illegible]
	[illegible]	1	[illegible]	
1032	[illegible]	6	[illegible] CLAMP	[illegible]
1020	[illegible]	[illegible]	ANGLE	[illegible]
1019	[illegible]	[illegible]	ANGLE	[illegible]
[illegible]	[illegible]	[illegible]	PLATE	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	SCREW	[illegible]
[illegible]	[illegible]	[illegible]	HANDLE	[illegible]
[illegible]	1030	1	[illegible]	[illegible]
[illegible]	1029	1	[illegible] PLATE	[illegible]
[illegible]	1028	1	DOOR ASSY	
1023	1027	48	STUD	[illegible]
1023	[illegible]	[illegible]	BLOCK	[illegible]
1023	1025	[illegible]	ANGLE	[illegible]
1023	[illegible]	[illegible]	PLATE	[illegible]
1001	1023	[illegible]	CORNER SUPPORT ASSY	
[illegible]	1022	16	GUSSET	[illegible]
[illegible]	1021	[illegible]	ANGLE	[illegible]
[illegible]	[illegible]	[illegible]	SUPPORT ASSY	
[illegible]	[illegible]	[illegible]	SUPPORT ASSY	
[illegible]	[illegible]	[illegible]	STIFFENER	[illegible]
[illegible]	[illegible]	[illegible]	TIE PLATE	[illegible]
[illegible]	[illegible]	[illegible]	TUBING	[illegible]
[illegible]	1015	[illegible]	TUBING	[illegible]
[illegible]	1014	4/4	TUBING	[illegible]
1001	1013	1	FRAME ASSY (TOP)	
1001	1012	1	FRAME ASSY (BOTTOM)	
[illegible]	1011	[illegible]	TUBING	[illegible]
[illegible]	1010	12/12	TUBING	[illegible]
[illegible]	1009	4/4	TUBING	[illegible]
1001	1008	1	FRAME ASSY (R H SIDE)	
1001	1007	1	FRAME ASSY (L H SIDE)	
1001	1006	1	FRAME ASSY (BACK)	
[illegible]	1005	13/12	TUBING	[illegible]
[illegible]	1004	[illegible]	TUBING	[illegible]
[illegible]	1003	4 4	TUBING	[illegible]
1001	1002	1	FRAME ASSY (FRONT)	
	[illegible]	1	[illegible] ASSY	

TOOL DRAWING
THE BOEING COMPANY
MOLDED CONTAINER MOLD
EVOLD R677059 P08
21

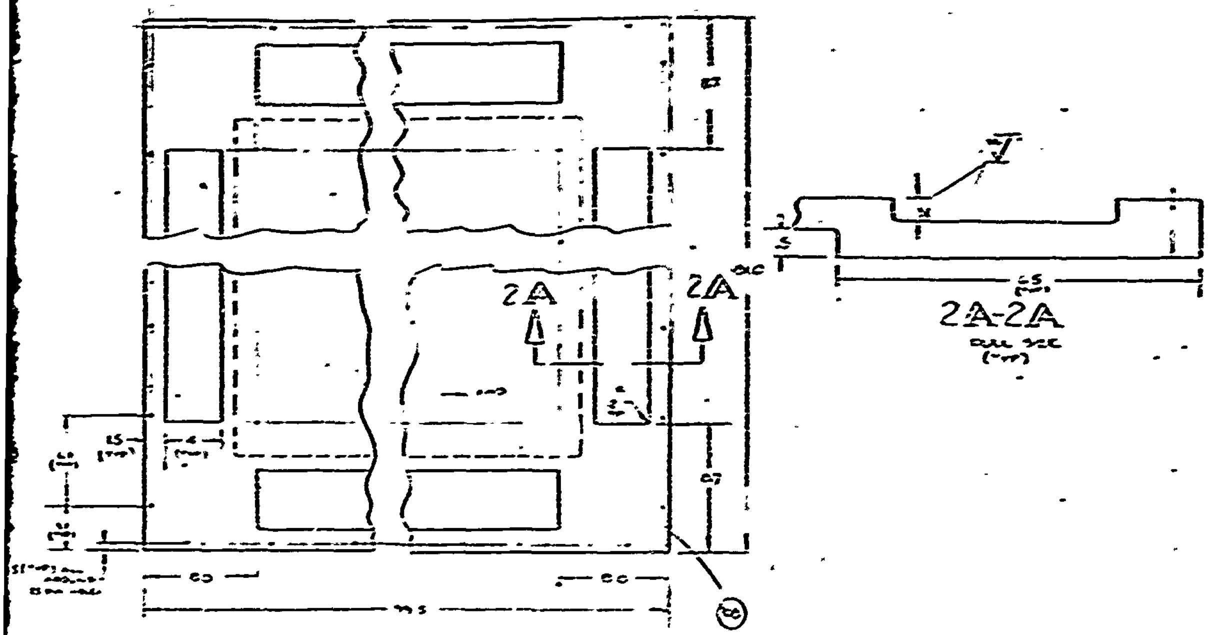
(2)





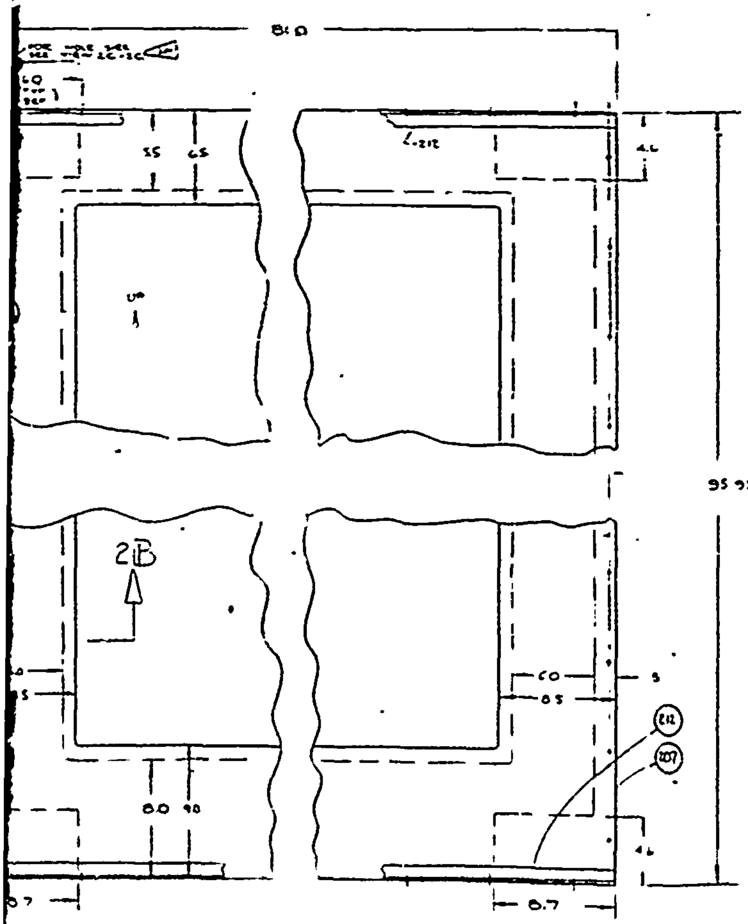


PANEL
FRONT PANEL ASSY
2D - 2D
½ SIZE
2C - 2C
½ SIZE
C/SINK & RIVET WITH .25 DIA RIVETS (TYP) DRIVE WITH NO HIGH & SHAVE
2B - 2B
½ SIZE
2E
2D
2C
2B
95.93
81.0
205 SIDE PANEL ASSY (L H.)
206 (R H OPP -205)
201 BACK
5
4
3



(202) BOTTOM PANEL

1/4 SIZE



(201) BACK PANEL ASSY

1/4 SIZE

RADII IN MACHINED CUTOUTS .2 (TYP)

TOLERANCES .XX ± .030 .X ± .060

MAKE HOLE PATTERN AT ASSY OF MOLD TO AGREE WITH ADJACENT PANELS.

205/206	213	4/4	ANGLE		AL ALLOY [illegible]
2C/203	212	2/2	ANGLE		AL ALLOY [illegible]
204	211	1	PLATE		AL 6061-T651 [illegible]
205/206	210	1/1	PLATE		[illegible]
203	209	1	PLATE		[illegible]
202	208	1	PLATE		[illegible]
201	207	1	PLATE		AL 6061-T651 [illegible]
	206	1	SIDE PANEL ASSY		
	205	1	SIDE PANEL ASSY		
	204	1	TOP PANEL		AL 6061 T651 [illegible]
	203	1	FRONT PANEL ASSY		
	202	1	BOTTOM PANEL		AL [illegible]
	201		BACK PANEL ASSY		

21

TOOL DRAWING

THE BOEING COMPANY

CAG

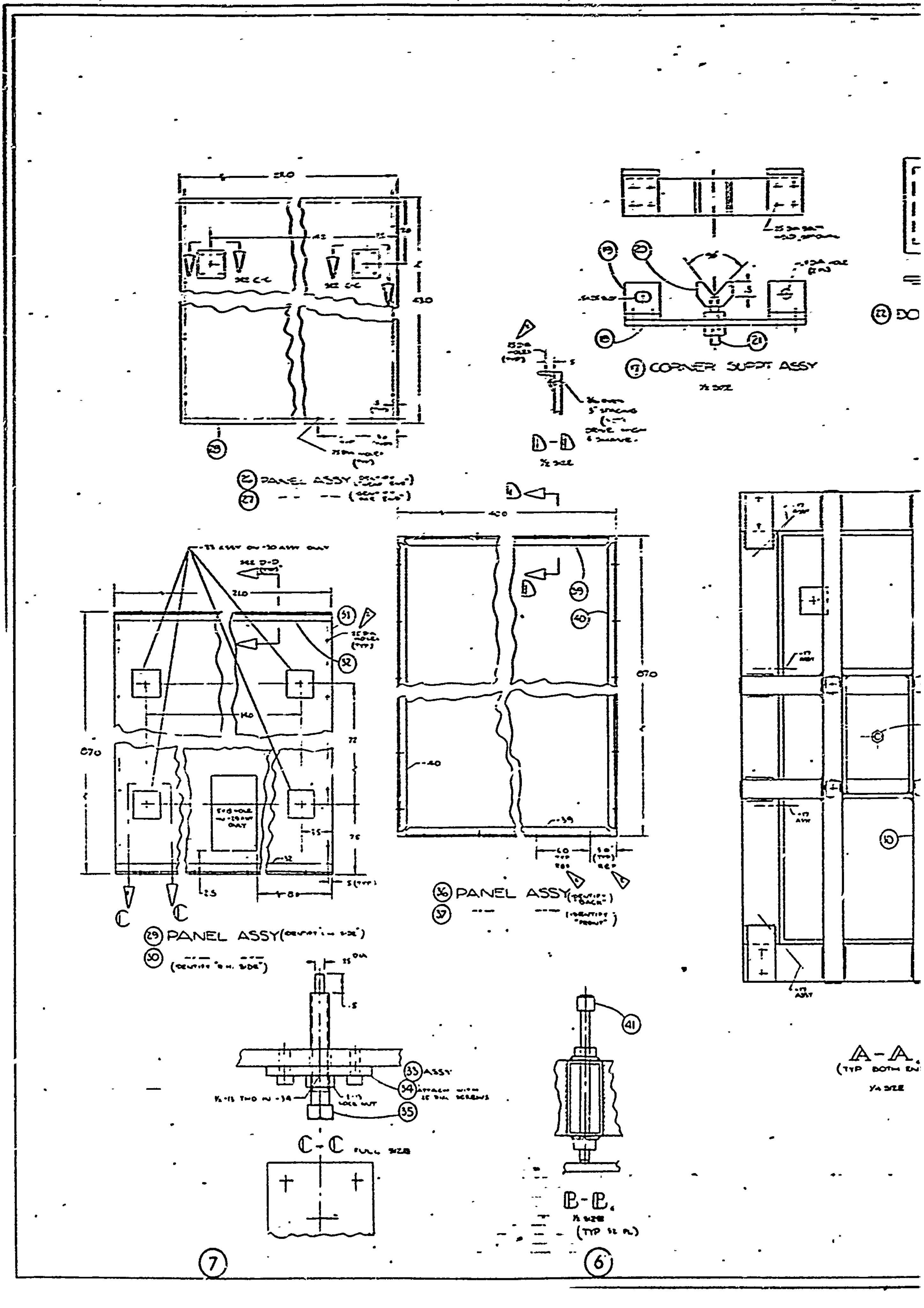
MOLDED CONTAINER MOLD

[illegible] 2

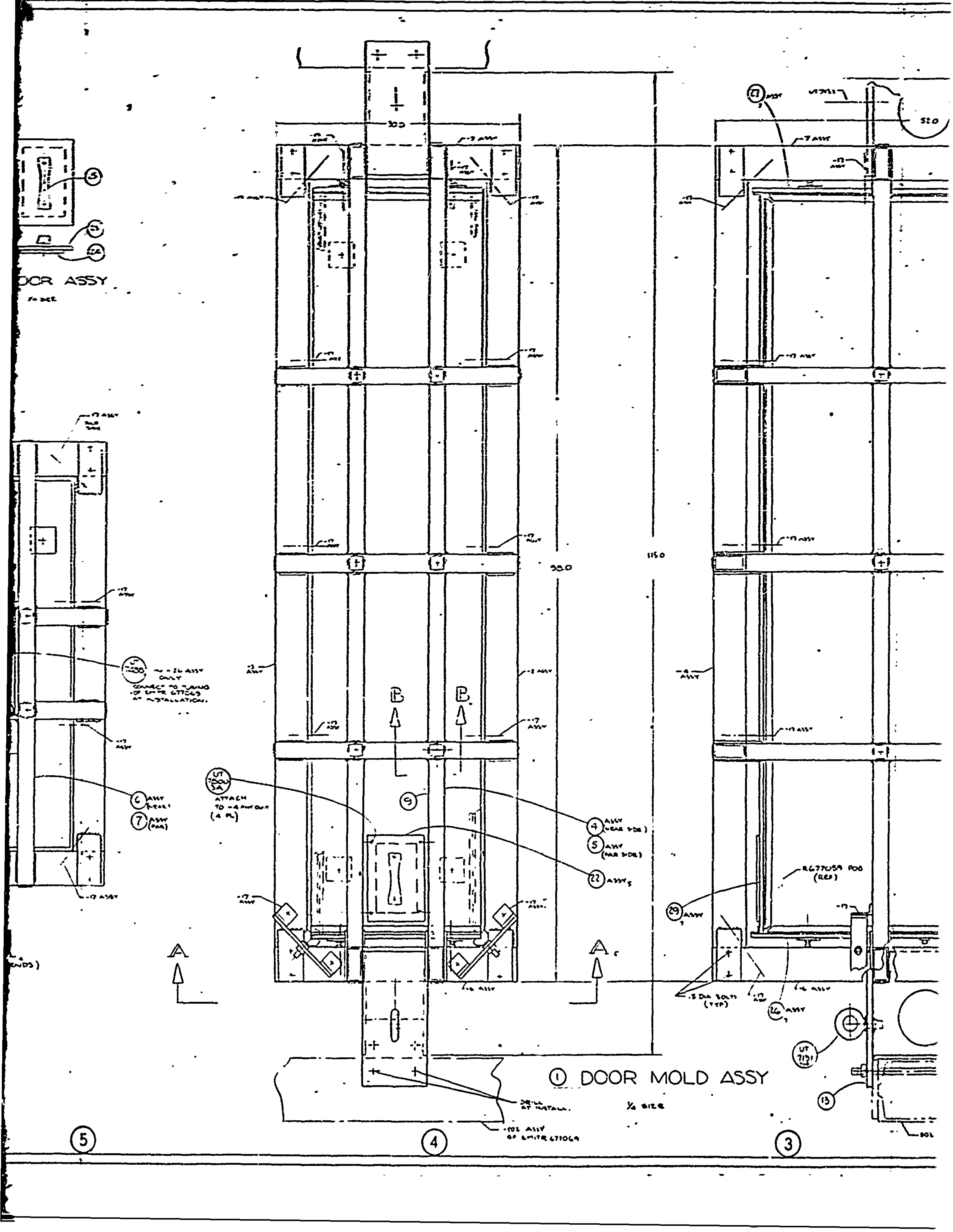
(3)

(2)

F-3



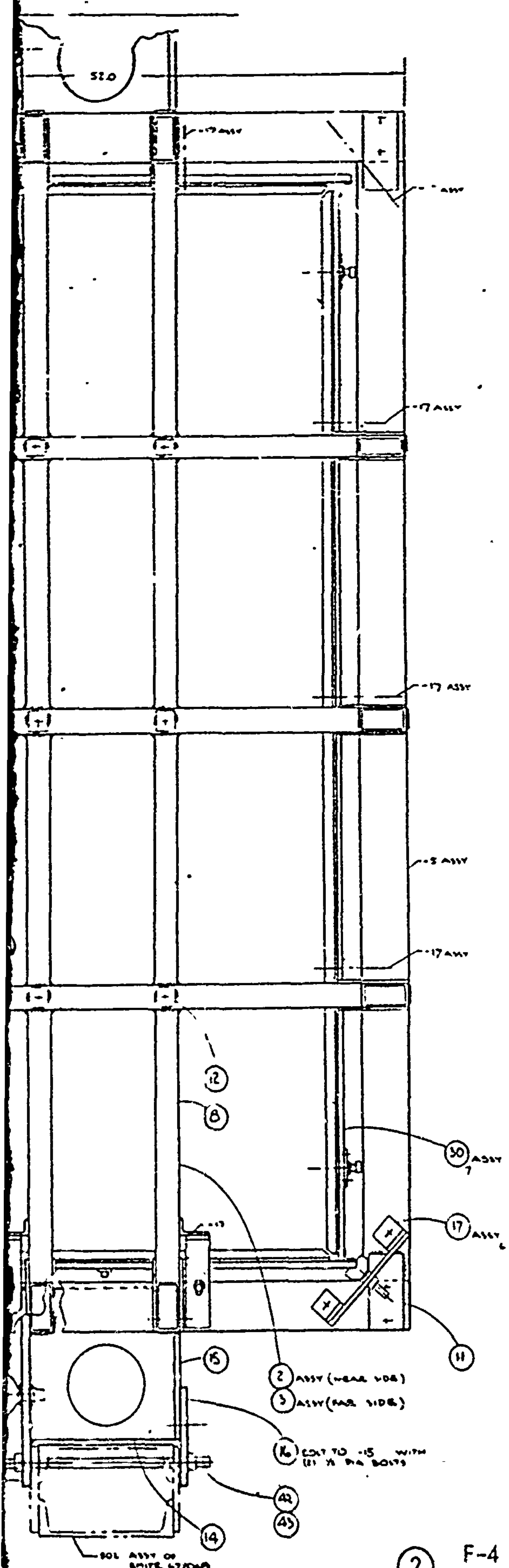
PANEL ASSY
CORNER SUPPT ASSY
D-D
PANEL ASSY
PANEL ASSY
C-C FULL SIZE
B-B
(TYP 32 PL)
A-A
7
6



DOOR ASSY
① DOOR MOLD ASSY
¼ SIZE
520
580
1150
300
B
B
A
A
4 ASSY (NEAR SIDE)
5 ASSY (FAR SIDE)
22 ASSY
6 ASSY (NEAR)
7 ASSY (FAR)
29 ASSY
26 ASSY
ATTACH TO -4 ASSY ONLY (4 PL)
CONNECT TO TUBING OF EMITR 677069 AT INSTALLATION.
RG77059 POD (REF)
.3 DIA BOLTS (TYP)
DRILL AT INSTALL.
-502 ASSY OF EMITR 677069
5
4
3

FUNCTION OF TOOL:

TO FACILITATE MOLDING OF PLASTIC ON DOORS OF CONTAINER R677059-PDD.



SCALE DWG FOR DIM'S NOT SHOWN
100° WELD PER TPS 20 WHERE SHOWN (¼ IN WELD)
JOIN ALL 6 PANELS WITH .25 DIA BOLTS

4 TOLERANCE .XX ± .030 .X ±.060

3 STL STAMP IDENTIFICATION ON FRAMES & PANELS TO FACILITATE REPEATED ASSY (SEE MATL LIST)

2 MAKE HOLES AT ASSY TO ASSEMBLE WITH ADJACENT PANELS

1 CUT AS REQD.

6/7	UT 7051	1/1	EYE BOLT		-14
26	UT 7499	1	NOZZLE		
4	UT 7800	4	TOGGLE CLAMP		-3A
	UT 6924	1	IDENT TAG		US ARMY PROP.
1	43	8	NUT		STL HEX NUT ½-10
1	42	4	ROD		HRS THREADED ROD ½-10 × 13
[illegible]	41	[illegible]	SCREW		SOC HD CAP SCREW ½-13 × 1
36/37	40	2/2	ANGLE		AL 6061-T6 ANG [illegible]
36/37	39	2/2	ANGLE		AL 6061-T6 ANG [illegible]
36/37	38	/1	PLATE		AL 6061-T651 ½ × 40 × 57
1	37	1	PANEL ASSY (FRONT)		
1	36	1	PANEL ASSY (BACK)		
33	35	8	SCREW		MAKE FROM ½ [illegible] SCREW
33	34	8	PLATE		HRS ¼ × [illegible]
4 29/30	33	[illegible]	SUPPORT ASSY		
29/30	32	2/2	ANGLE		AL 6061-T6 ANG [illegible]
29/30	31	/1	PANEL		AL 6061-T651 ½ × 31 × 87
1	30	1	PANEL ASSY (R H)		
1	29	1	PANEL ASSY (L H)		
36/37	28	1/1	PANEL		AL 6061-T651 ½ × 2 × 41
1	27	1	PANEL ASSY [illegible]		
1	26	1	PANEL ASSY [illegible]		
23	25	1	HANDLE		SHOP MADE
22	24	1	PLATE		AL 6061-T651 ½ × 5 × 8
22	23	1	PLATE		AL 6061-T651 ½ × 7 × 9
1	22	1	DOOR ASSY		
17	21	28	STUD		HRS ½-13 UNC × 2½
17	20	28	BLOCK		HRS 1¼ × 2 × 2
17	19	56	ANGLE		HRS ANG 2½ × 2½ × ¼ × 2
17	18	28	PLATE		HRS ½ × 2 × 4
1	17	28	CORNER SUPPORT ASSY		
6/7	16	1/1	PLATE		HRS ½ × 8 × 8
6/7	15	1/1	PLATE		HRS ½ × 8 × 8½
6/7	14	2/2	PLATE		HRS ½ × 12 × 12½
6/7	13	1/1	PLATE		HRS ¼ × 8 × 16
[illegible]	12	[illegible]	STIFFENER		HRS ¼ × 1½ × 1½
[illegible]	11	[illegible]	TIE PLATE		HRS ¼ × 3 × 6
[illegible]	10	[illegible]	TUBING		RECT STL TUBING 2 × 4
[illegible]	9	[illegible]	TUBING		— " —
[illegible]	8	[illegible]	TUBING		— " —
1	7	1	FRAME ASSY (FAR END)		
1	6	1	FRAME ASSY (NEAR END)		
1	5	1	FRAME ASSY R H SIDE		
1	4	1	FRAME ASSY L H SIDE		
1	3	1	FRAME ASSY (BACK)		
1	2	1	FRAME ASSY (FRONT)		
		1	DOOR MOLD ASSY		

TOOL DRAWING

THE BOEING COMPANY

MOLDED CONTAINER DOOR MOLD

E2Y-DR677059 PDD 1

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